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MSC- 05531

NASA CR-
141910

# SKYLAB PROGRAM

## EARTH RESOURCES EXPERIMENT PACKAGE

GROUND TRUTH DATA

FOR TEST SITES (SL-2)

(NASA-CR-141910) SKYLAB PROGRAM EARTH RESOURCES EXPERIMENT PACKAGE: GROUND TRUTH DATA FOR TEST SITES (SL-2) (Martin Marietta Corp.) 85 p HC $4.75 CSCL 08G

N75-30628

Unclas
G3/43 26370

CONTRACT NAS8-24000

AMENDMENT JSC-14S

*National Aeronautics and Space Administration*

***LYNDON B. JOHNSON SPACE CENTER***

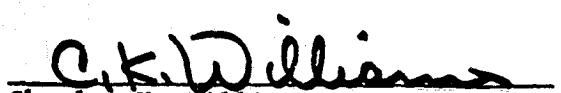
***Houston, Texas***

AUGUST 15, 1973

# GROUND TRUTH DATA

# FOR TEST SITES (SL-2)

Approved by:



Charles K. Williams
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and Technical Integration, JSC/KA

Contract NAS8-24000
Amendment JSC-14S

Skylab Program
Lyndon B. Johnson Space Center

## FOREWORD

This document is submitted by MMC in accordance with the requirements of Annex I to Exhibit A, Statement of Work, Part I, Data Requirements List (DRL), of Contract NAS8-24000, Amendment JSC-14S, Line Item 296 and was performed under WBS-02216.

Any questions regarding the contents of this document should be addressed to NASA JSC, Earth Resources Program Office, Mail Code HA.

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## 1.0 INTRODUCTION

During the SL-2 Skylab mission, field measurements were performed at selected ground sites in order to provide comparative calibration measurements for the EREP sensors. Specifically, the solar (400 to 1300 nm - namometers) and thermal (8-14 μm - micrometers) were addressed.

Sites employed for the thermal measurements consisted of "warm" and "cold" water lakes. These included Lake Pleasant, Arizona ("warm water"), Vallecito Reservoir, Colorado ("cold water"), and Twin Lakes Reservoir, Colorado ("cold water"). In general, the thermal brightness temperature of the lake water, the temperature and humidity profile above the lake, and near surface meteorology (wind speed, pressure, etc.) were measured near the time of overpass.

Sites employed for the solar radiation measurements included two desert type sites - Wilcox Playa, Arizona and the Great Salt Lake Desert, Utah. Ground measurements consisted of direct solar radiation - optical depth, diffuse solar radiation, total solar radiation, target directional (normal) reflectance, target hemispherical reflectance, and near surface meteorology (wind speed, pressure, etc.)

## 2.0 THERMAL INFRARED CALIBRATION MEASUREMENTS AND ANALYSES

### 2.1 INSTRUMENTATION AND TECHNIQUES

The thermal (8-14 μm) brightness temperature of the lake waters were measured with a Barnes PRT-5 Radiation Thermometer. This instrument has a sensitivity range of -20°C to +75°C, a field-of-view of 2°, an accuracy of .5°C, and a stability (electronics) of better than .1%. A detailed calibration of this instrument was performed and is given in the appendix.

A Colspan Environmental Systems Co. LARS (Low Altitude Rocket System) was used to measure the altitude distribution of atmospheric temperature and humidity. This system is comprised of a 25 in. rocket and launch pad, (capable of a 3300 ft. altitude ascent), and a ground receiving station (403 MHz). The rocket is launched on-site, ascends to approximately 3300 ft. above terrain, deploys a parachute, and during descent measures temperature (coated bead thermistor) and humidity (radiosonde carbon element, ML-476). The system accuracy equals the accuracy of the sensors plus 1.0% of recorder span. The temperature sensors accuracy is ± .2°C from 0 to 50°C and ± .4°C from -40 to 0°C. The humidity sensors accuracy is ± 5% above 0°C, with an operating range of 10 to 100% R.H. Detailed calibration and analysis techniques for this system are given in the appendix.

Near surface meteorology measurements were taken with a conventional sling psychrometer wet bulb and dry bulb, a cup anemometer, and an aneroid barometer. Accuracy of the wet bulb temperatures is $1^{\circ}F$, the barometer accuracy is $\pm$ .1 in. of Hg, and the wind speed measurements have a $\pm$ 2 m.p.h. accuracy.

## 2.2 MEASUREMENTS AND ANALYSES

### 2.2.1 Lake Pleasant, Arizona

Date: 03 Jun 1973

EREP Pass: 3; Groundtrack: 6; Revolution: 290/291

Site Coordinates: $33^{\circ}52'N$; $112^{\circ}16'W$

Time of Overpass: 154:19:25:46 GMT

2.2.1.1 General Conditions: Low cumulus clouds build up commenced about 1000 MST in the North and South. By overpass cumulus approached $30^{\circ}$ above horizon and other scattered cumulus around perimeter of horizon. No cirrus clouds were visible, and no shadows were ever present on the lake itself.

2.2.1.2 Near Surface Meteorology

Table 2.1 Pleasant Lake Near Surface Meteorology

| TIME (MST) | DRY BULK | WET BULB | BARO-METRIC PRESSURE | WIND SPEED/ DIRECTION | LOCATION |
|---|---|---|---|---|---|
| 1152 | | | | Calm | On Lake<br>At Airport |
| 1205 | | | 28.42 in<br>(721.9 mm) | | |
| 1215 | 89°F<br>(31.7°C) | 67°F<br>(19.4°C) | | | At Airport |
| 1220 | 31.8°C<br>(89.2°F) | | | | At Airport |
| 1225 | | | | 4-6 mph<br>from NW | |
| 1232 | 81°F<br>(27.2°C) | 68°F<br>(20.0°C) | | | At Lake |

2.2.1.3 Temperature and Humidity Profile: A rocket sonde was launched to 3300 ft (1.005 km) above terrain. Upon descent temperature and humidity were measured. However, the descent parachute failed to deploy. This necessitated a special analysis technique that is explained in the Appendix.

Figures 2.1 and 2.2 show the temperature and humidity profile as a function of altitude above sea level (A.S.L.) immediately above the site.

The rocket sonde was launched at an airport landing strip located approximately 1.5 miles (2.42 km) south of the lake and at an altitude of 200 feet (61 meters) above the lake level. Launch was at +5 min. of overpass.

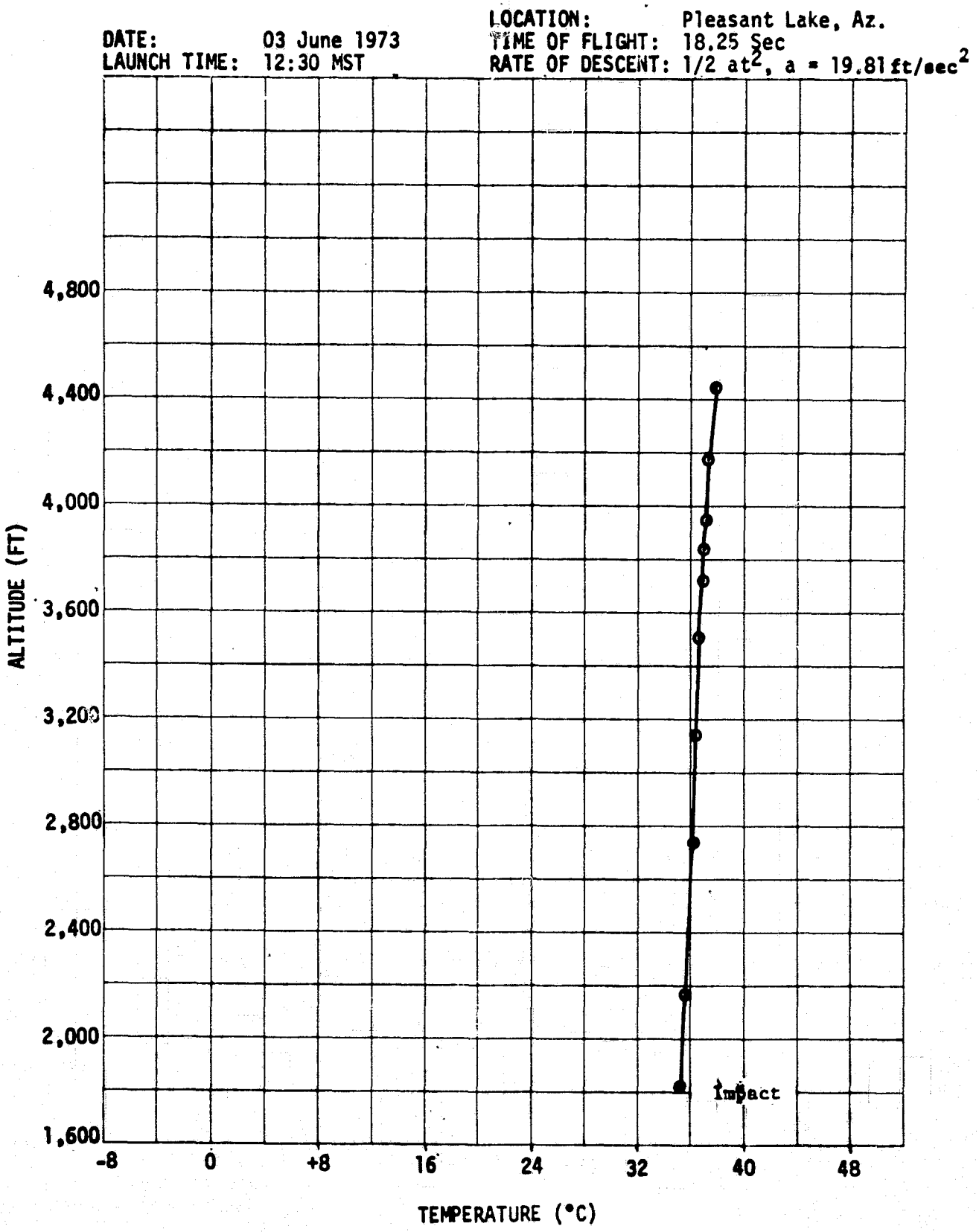



Figure 2.1 Rocketsonde Temperature Profile

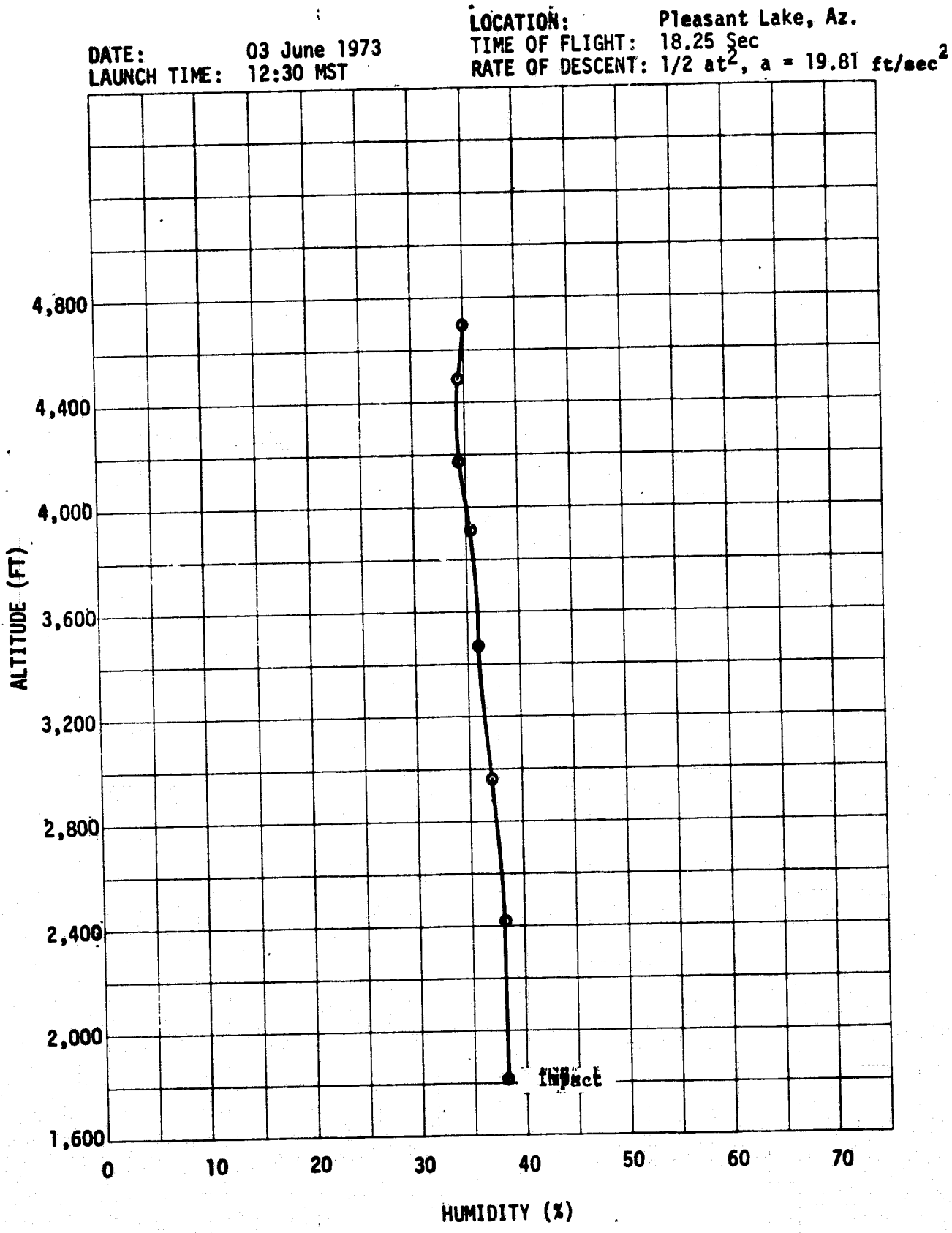



Figure 2.2 Rocketsonde Humidity Profile

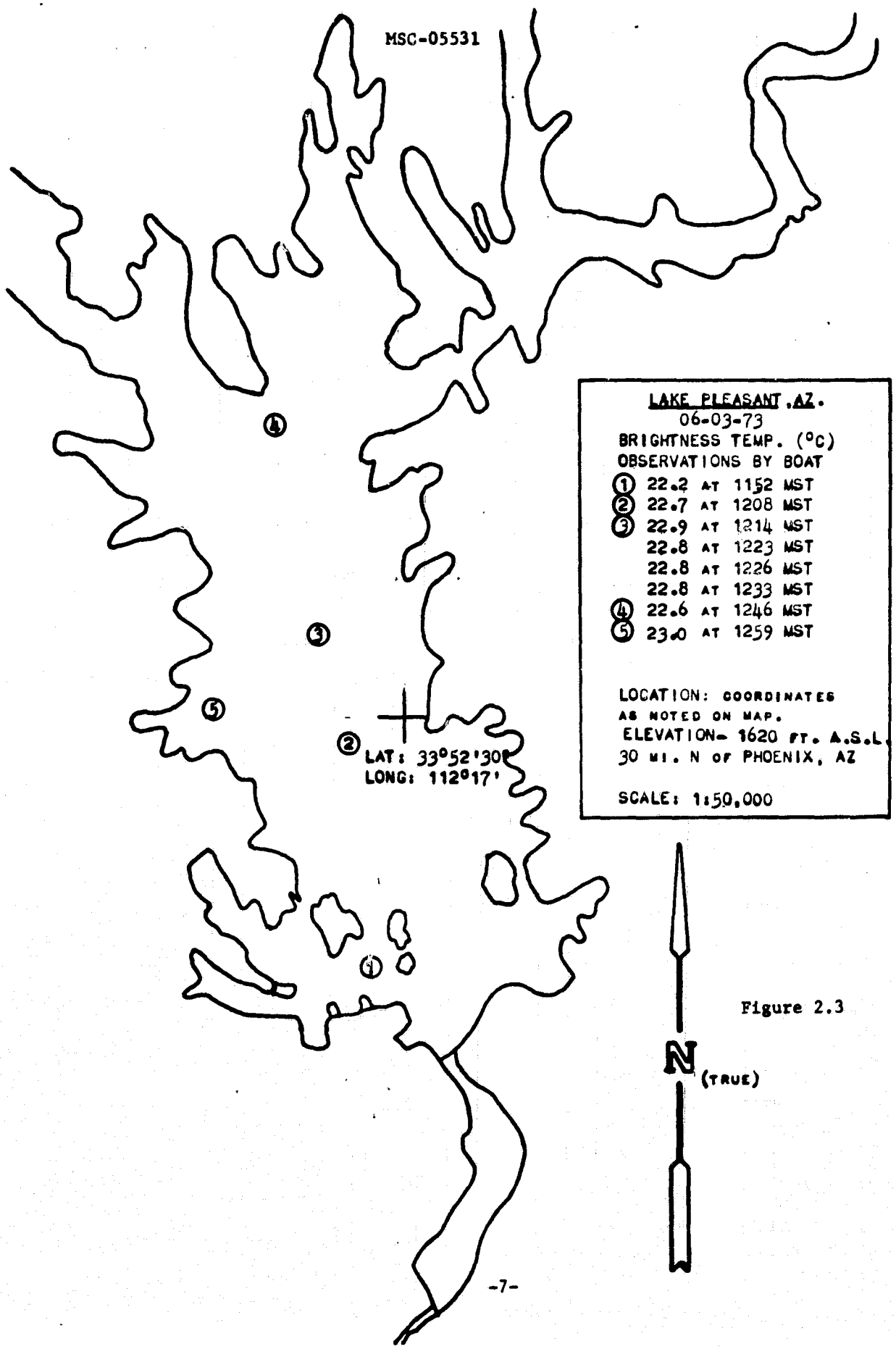

LAKE PLEASANT, AZ.
06-03-73
BRIGHTNESS TEMP. (°C)
OBSERVATIONS BY BOAT
① 22.2 AT 1152 MST
② 22.7 AT 1208 MST
③ 22.9 AT 1214 MST
22.8 AT 1223 MST
22.8 AT 1226 MST
22.8 AT 1233 MST
④ 22.6 AT 1246 MST
⑤ 23.0 AT 1259 MST
LOCATION: COORDINATES AS NOTED ON MAP.
ELEVATION- 1620 FT. A.S.L.
30 MI. N OF PHOENIX, AZ
SCALE: 1:50,000
LAT: 33°52'30"
LONG: 112°17'
N (TRUE)

Figure 2.3

2.2.1.4 Brightness Temperature: Radiometric temperatures were taken at five different locations on the lake. Three of the locations are in the middle of the lake and two locations were near the banks at the lake. Measurements were made from a small boat. The data analyses are given in the Appendix. A map of the lake is shown in Figure 2.3 displaying the locations of measurements and an information box outlining times and brightness temperatures. Measurements were made ± 35 min. of overpass.

2.2.2 Vallecito Reservoir, Colorado

Date: 05 June 1973

EREP Pass: 5; Ground Track: 34; Revolution: 318/319

Site Coordinates: 37°25'N; 107°33'W

Time of Overpass: 156:17:59:16 GMT

2.2.2.1 General Conditions: The atmospheric conditions was extremely clear during all data collections.

2.2.2.2 Near Surface Meteorology:

Table 2.2 Vallecito Near Surface Meteorology

| TIME (MDT) | DRY BULB | WET BULB | BAROMETRIC PRESSURE | WIND SPEED & DIRECTION | LOCATION |
|---|---|---|---|---|---|
| 1025 | | | 22.92 in of Hg | | |
| 1030 | 52°F (11.1°C) | 42°F (5.6°C) | | | |
| 1110 | 55°F (12.8°C) | | | | At Boat Dock |
| 1135 | | | | 5 mph from S.E. | At Inlet |
| 1140 | 59°F (15.0°C) | 49°F (9.4°C) | | | At Inlet |
| 1200 | 52°F (11.1°C) | 49°F (3.3°C) | | | 1200 ft (.366 km) above lake |

2.2.2.3 Temperature and Humidity Profile: A rocket sonde electronics package was dropped from a helicopter at an altitude of 15,000 ft (4.57 km) A.S.L. and descended to the ground level of 7,850 ft (2.39 km) A.S.L.. The drop was successful and data reduction was straight forward. The sonde descended on a parachute at a constant velocity of 26 ft/sec (7.925 meters/sec).

Figures 2.4 and 2.5 show the temperature and humidity profile as a function of altitude (A.S.L.) immediately above the site. The ground receiving station was located on the lake and the sonde landed near the shoreline.

A temperature range from -0.6°C to 17.0°C and a humidity range from 9.5% to 39% was measured. Drop time of sonde was at +15 min of overpass.

2.2.2.4 Brightness Temperature: Radiometric temperatures were taken during two time intervals. The first observations were made from a helicopter at an altitude of 300 ft (91.44 meters) above lake level detecting a nearly constant brightness temperature around the perimeter of the lake about 1/3 the distance towards the middle. The second set of measurements were taken during overpass from a boat located near the middle of the lake. Calibration corrections were applied to the field data as explained in the appendix.

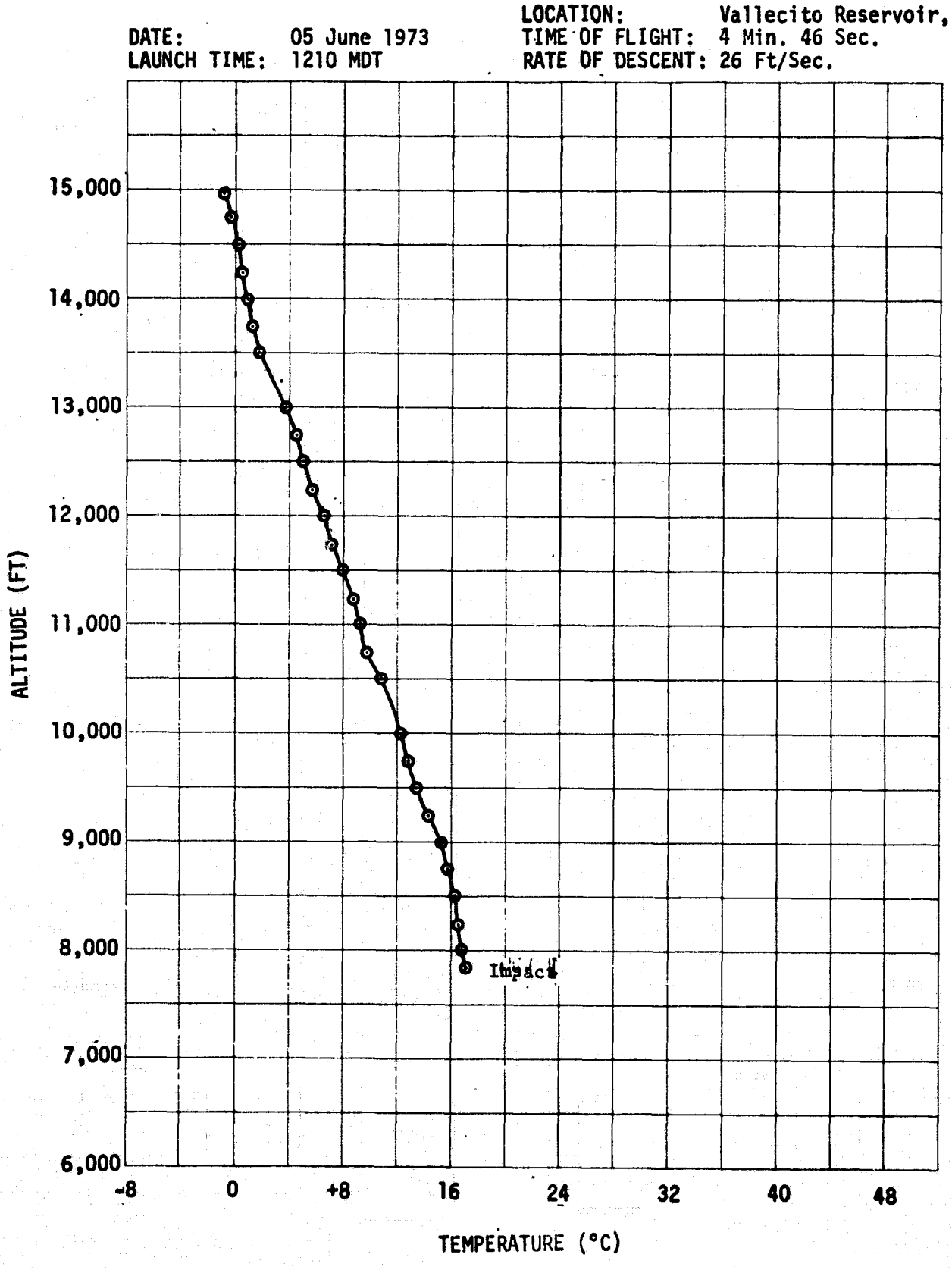



Figure 2.4 Rocketsonde Temperature Profile

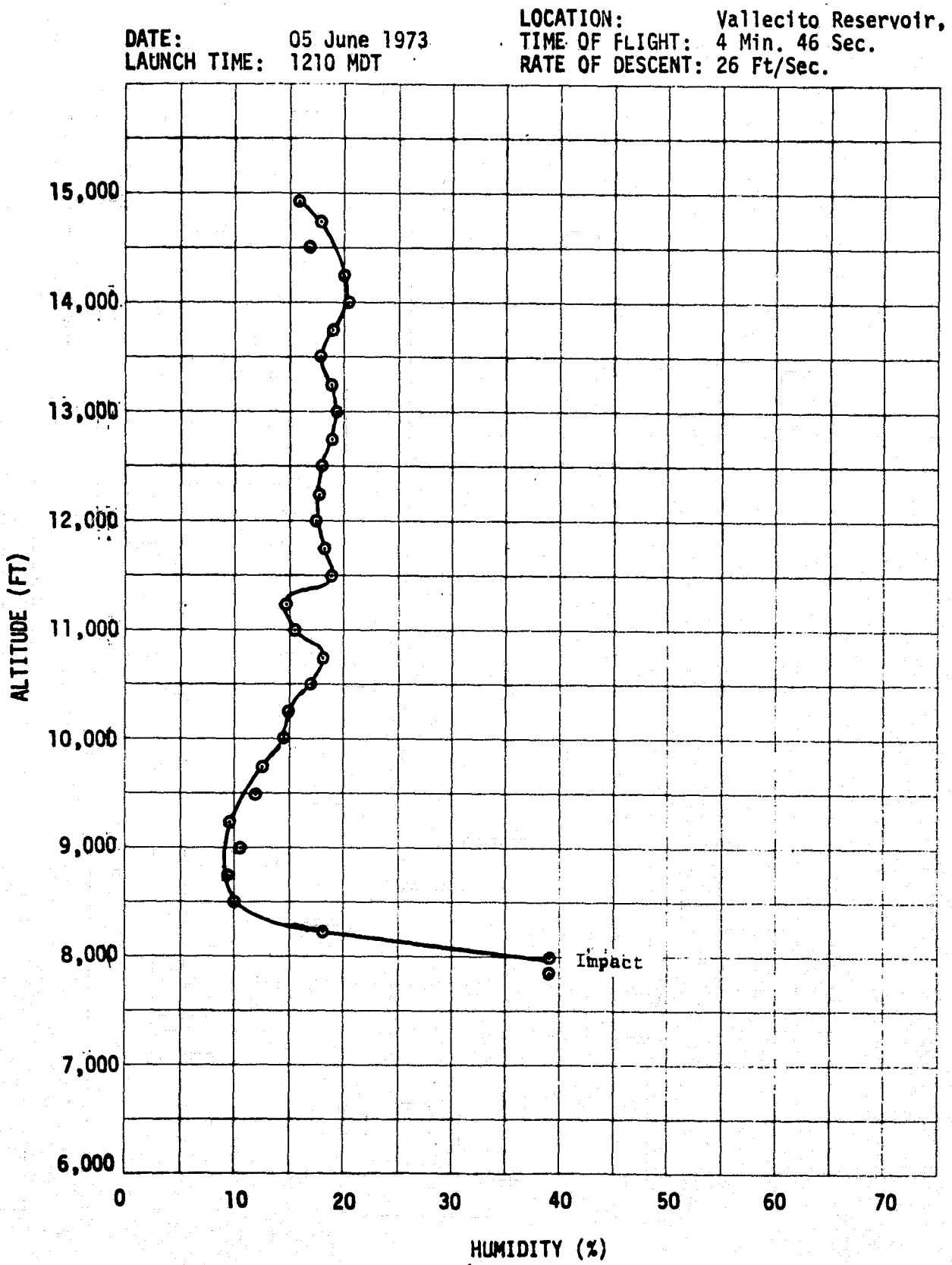
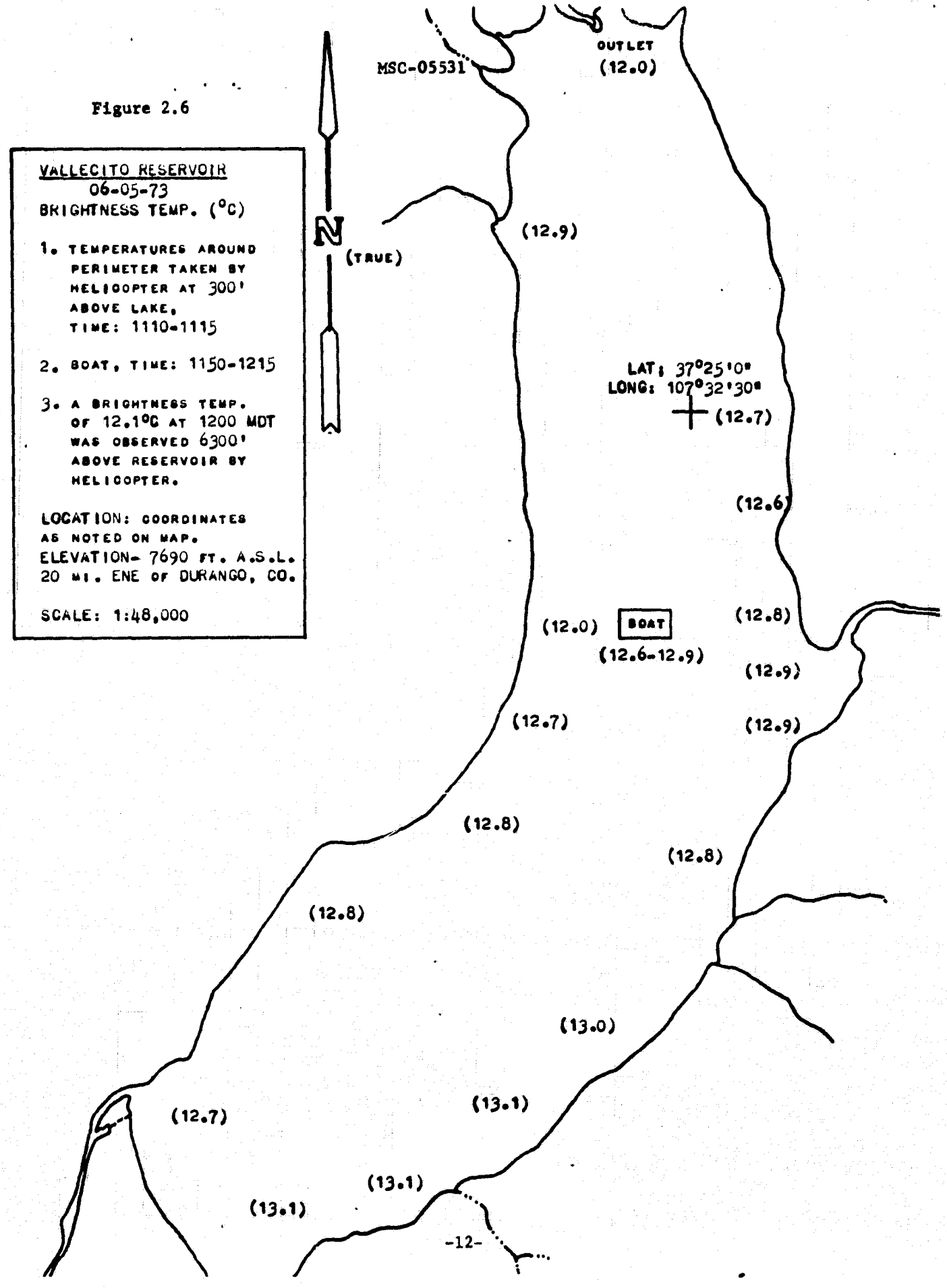



Figure 2.5 Rocketsonde Humidity Profile

Figure 2.6


VALLECITO RESERVOIR
06-05-73
BRIGHTNESS TEMP. (°C)
1. TEMPERATURES AROUND PERIMETER TAKEN BY HELICOPTER AT 300' ABOVE LAKE, TIME: 1110-1115
2. BOAT, TIME: 1150-1215
3. A BRIGHTNESS TEMP. OF 12.1°C AT 1200 MDT WAS OBSERVED 6300' ABOVE RESERVOIR BY HELICOPTER.
LOCATION: COORDINATES AS NOTED ON MAP.
ELEVATION- 7690 FT. A.S.L.
20 MI. ENE OF DURANGO, CO.
SCALE: 1:48,000
N
(TRUE)
MSC-05531
OUTLET
(12.0)
(12.9)
LAT: 37°25'0"
LONG: 107°32'30"
(12.7)
(12.6)
(12.0)
BOAT
(12.6-12.9)
(12.8)
(12.9)
(12.9)
(12.7)
(12.8)
(12.8)
(12.8)
(13.0)
(13.1)
(12.7)
(13.1)
(13.1)

A map of the reservoir is shown in Figure 2.6 displaying in parenthesis the brightness temperatures taken by air -50 min, of overpass and the location of the boat measurements and temperatures in parenthesis next to boat box. Boat measurements were taken from -9 min. to +16 min. of overpass.

2.2.3 Twin Lakes Reservoir, Colorado

Date: 11 Jun 1973

EREP Pass: 8; Ground Track: 48; Revolution: 403/404

Site Coordinates: 39°05'N; 106°20'W

Time of Overpass: 162:15:17:08 GMT

2.2.3.1 General Conditions: Atmospheric conditions were not desirable because of high altitude cirrus clouds that persisted throughout the mission.

2.2.3.2 Near Surface Meteorology

Table 2.3 Twin Lakes Near Surface Meteorology

| TIME (MDT) | DRY BULB | WET BULB | BAROMETRIC PRESSURE | WIND SPEED & DIRECTION | LOCATION | COMMENTS |
|---|---|---|---|---|---|---|
| 0850 | | | | 0 mph | Middle of Lake | Lake very smooth |
| 0917 | 62°F (16.7°C) | 49°F (9.4°C) | | | Middle of Lake | Air temp 17°C |
| 1045 | 49°F (9.4°C) | 38°F ( °C) | | | Independence snowfield | Pass |

2.2.3.3 Temperature and Humidity Profile: A rocketsonde was launched to 3300 ft (1.005 km) above terrain the humidity and temperature were measured. Parachute problems were encountered as the after body remained attached to the electronics package and the parachute failed to deploy properly. Because of this malfunction, the normal descent rate was not achieved. A special data analysis was performed that is explained in the appendix.

Figures 2.7 and 2.8 show the temperature and humidity profile as a function of the absolute altitude immediately above the site. The sonde was launched from a hillside near the shoreline and landed close by the launch site. Launch was achieved at overpass.

2.2.3.4 Brightness Temperature: Radiometric temperatures were taken at 6 locations on lake, two of which are not defined on the data profile. The first location was in the middle of the lake and the measurement was 12.3°C at 0835 MDT. The last location was 400 yards off-shore of the Twin Lakes Lodge on north side of lake. Brightness temperature was 11.5°C at 0929 MDT. The other measurements are defined on the data profile. All measurements at Twin Lakes Reservoir were taken from a boat and the calibration correction factors have been applied as explained in the appendix.

A map of the lake is shown on Figure 2.9 displaying the location of the measurements taken from -27 min to +3 min of overpass and an information box outlining times and brightness temperatures.



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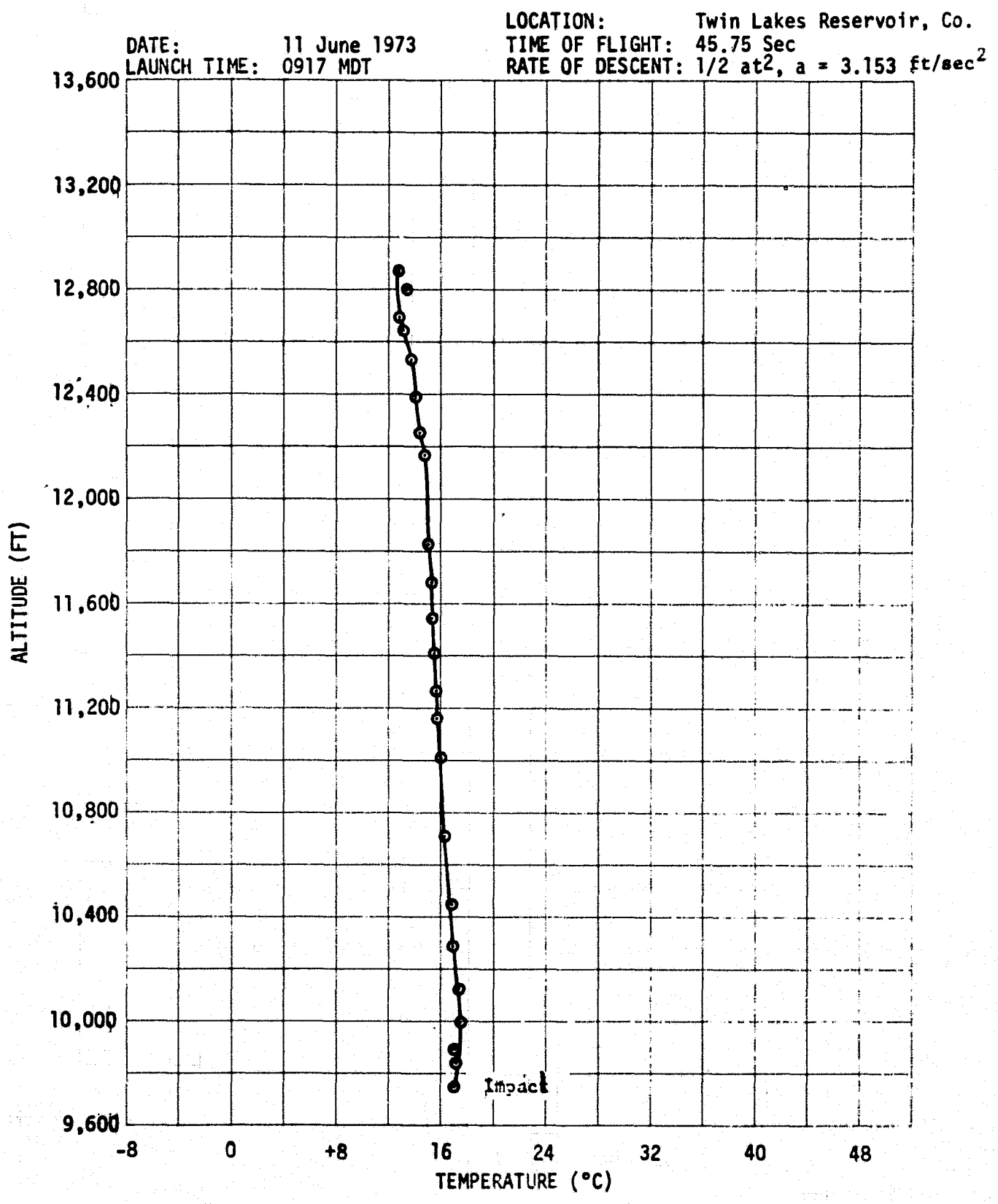


Figure 2.7 Rocketsonde Temperature Profile

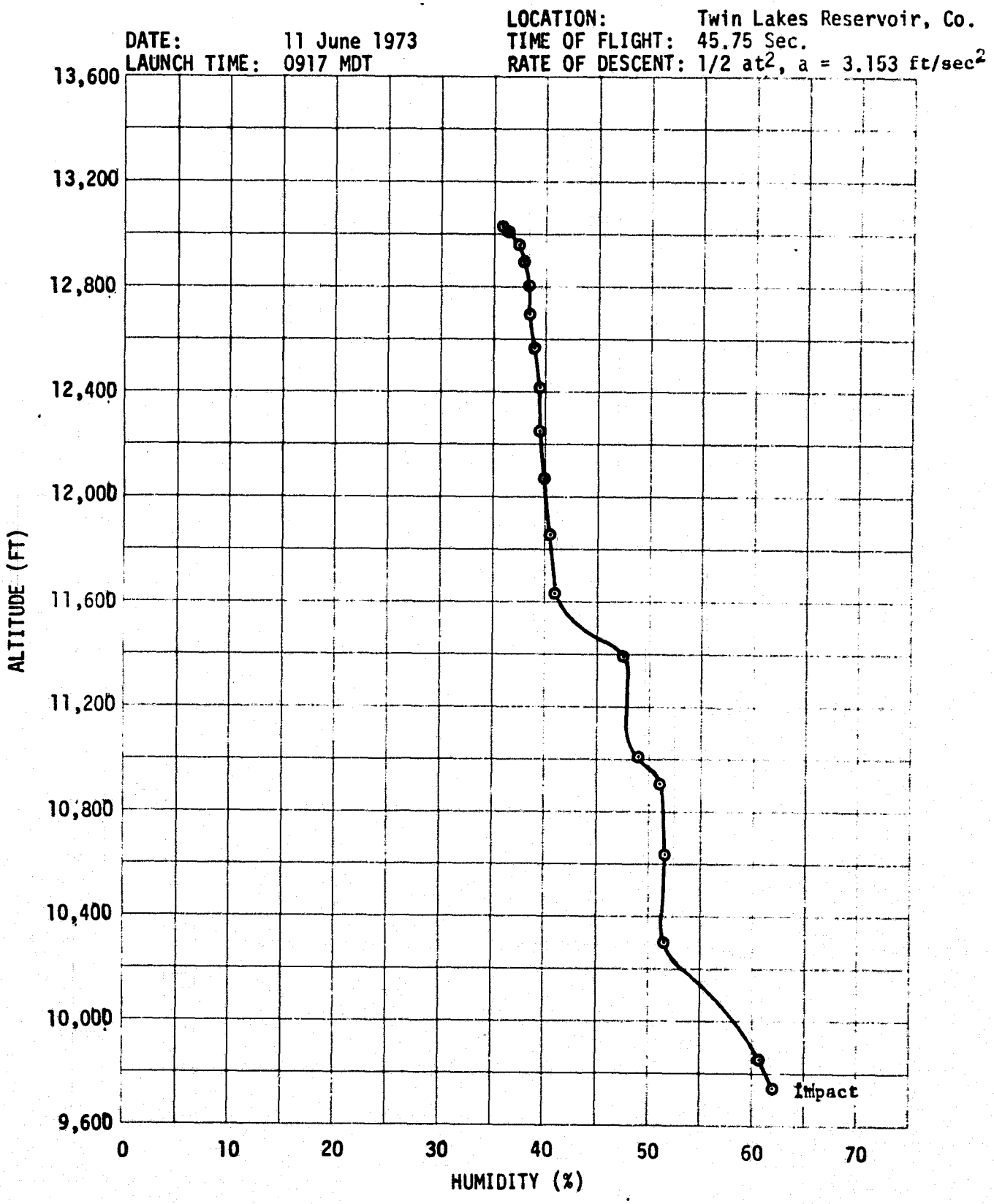


Figure2.8 Rocketsonde Humidity Profile

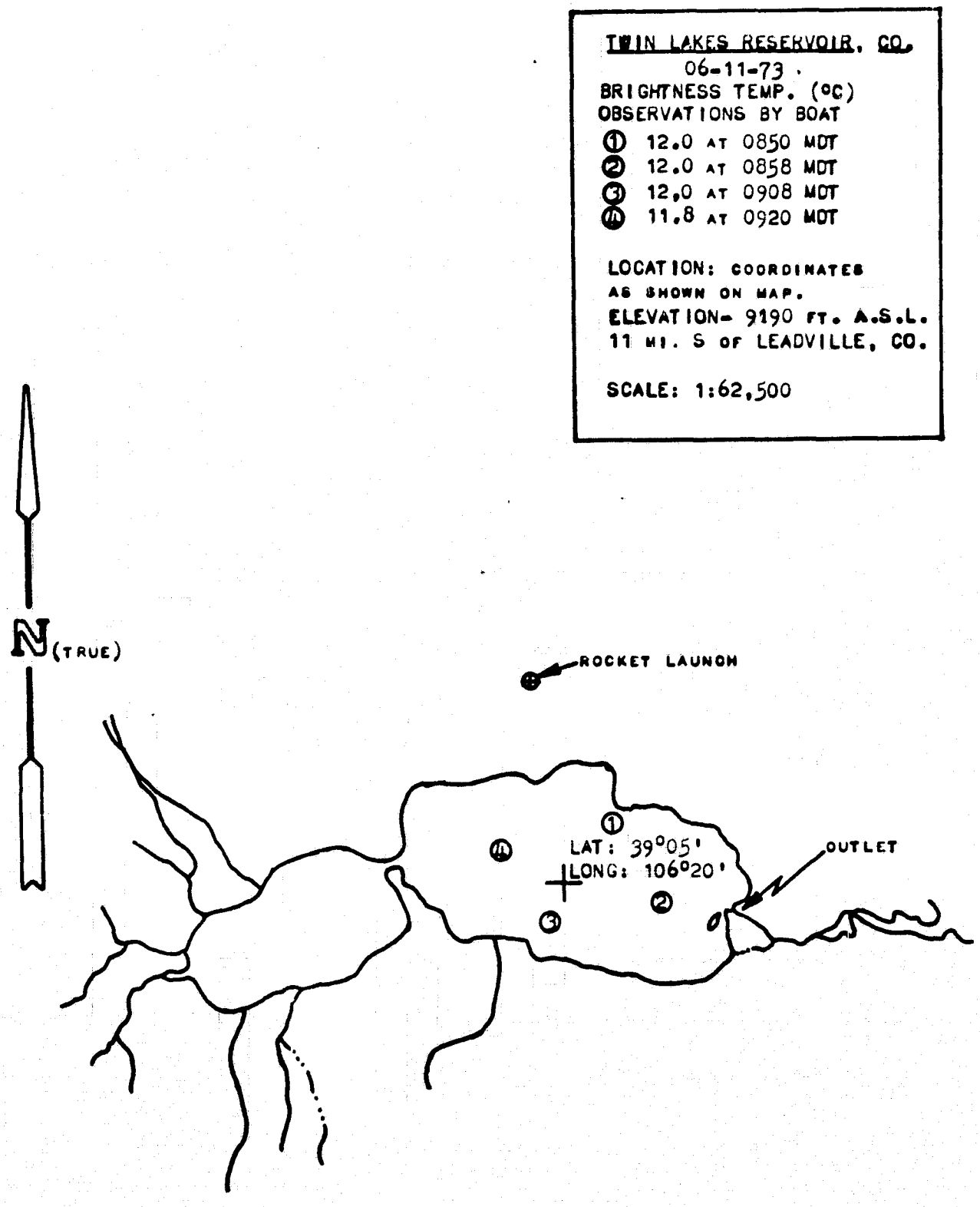


FIGURE 2.9 TWIN LAKES BRIGHTNESS TEMPERATURE DISTRIBUTION

## 3.0 SOLAR RADIATION CALIBRATION MEASUREMENTS AND ANALYSES

### 3.1 INSTRUMENTATION AND TECHNIQUES

I.S.C.O. (Instrumentation Specialties Co.) spectroradiometers were used to measure direct, diffuse and total solar radiation, and target reflectance from 400 to 1300 nm (nanometers). This instrument uses a wedge-interference filter system with a 15 nm bandwidth over the 400 to 750 nm region and a 30 nm bandwidth over the 750 to 1300 nm region. The sensing element is a stable, precision planar photodiode, and a light chopper system permits automatic zero and dark current adjustments 160 times a second. The instrument uses a fiber optics probe with a diffuser mounted on the end, as the light gathering element. The diffuser is made of Teflon and has a true cosine response.

The total and diffuse solar radiation were measured by simply placing the diffuser face up and level at the end of a tripod extension arm. The diffuse solar radiation was obtained by shading the diffuser from the direct solar beam. One complete I.S.C.O. instrument, including an automatic scanning recorder, was used for these measurements along with measurements of target directional and hemispherical reflectance.

The targets hemispherical reflectance was derived by first measuring the incoming total solar radiation and second, turning the diffuser over ($180^{o}$) and measuring the up welling radiation

from the target. Each scan, from 400 to 1300 nm required about 3 minutes time. During all scans, the broad-band (400-1100 nm) total solar radiation was measured with a Y.S.I. pyranometer. This allowed detection of any erratic changes in incoming solar radiation, during the ISCO scans.

The targets directional, normal to the surface, reflectance was measured by removing the diffuser from the fiber optics collector and measuring the radiance from a calibrated "white" and "gray" reflectance standards, and then measuring the radiance from the target. The area viewed was approximately a 5 in. diameter circle.

The direct solar beam was measured with an ISCO spectro-radiometer operated in the manual scan mode. This results in maximum accuracy, wavelength integrity, and precision. This is required for maximum accuracy on subsequent derivations of atmospheric optical depth. A $6^{o}$ collimator was attached over the diffuser collector in order to measure the direct beam.

The ISCO spectroradiometer was laboratory calibrated using a ribbon filament tungsten type standard (traceable to N.B.S.) lamp. This results in an absolute accuracy of $\pm$ 4% on the 400 to 750 nm region, and a $\pm$ 7% absolute accuracy in the 750 to 1300 nm region. The results of the calibration of the I.S.C.O. (SR30109) used to measure total and diffuse solar radiation,

are given in the appendix. The I.S.C.O. was calibrated in terms of wavelength at the factory; plus, continuous checks are made by periodically placing a Schott BG-36 filter, having known absorption bands, in the light path. The I.S.C.O. recorded data can be read to .5%, and has been found to be repeatable to approximately 1 to 3%, depending on wavelength and gain setting.

## 3.2 MEASUREMENTS AND ANALYSES

### 3.2.1 Great Salt Lake Desert, Utah

**Date:** 05 Jun 1973

**EREP** Pass: 3; Ground Track 34; Rev. 318/319

Time of overpass: 156:17:57:45 GMT

#### 3.2.1.1 Total and Diffuse Solar Radiation

The absolute (microwatts $cm^{-2}$ $nm^{-1}$) quantities of total* and diffuse solar radiation, near time of overpass, are shown in Figures 3.1 and 3.2. The ratio of diffuse to total solar radiation is shown in Figure 3.3; this is a parameter that is sensitive to atmospheric clarity/aerosols. As such, it will be useful for subsequent analyses of sensor performance, and for comparisons of atmospheric clarity between different test sites and for different times.

Several measurements of total and diffuse solar radiation were made during the period prior to and after the overpass. The raw spectroradiometer data was overviewed for repeatibility/precision. The data closest to overpass was then analyzed for absolute quantities.

*575 nm point is interpolated using spectral/intensity character of Figure 3.19.

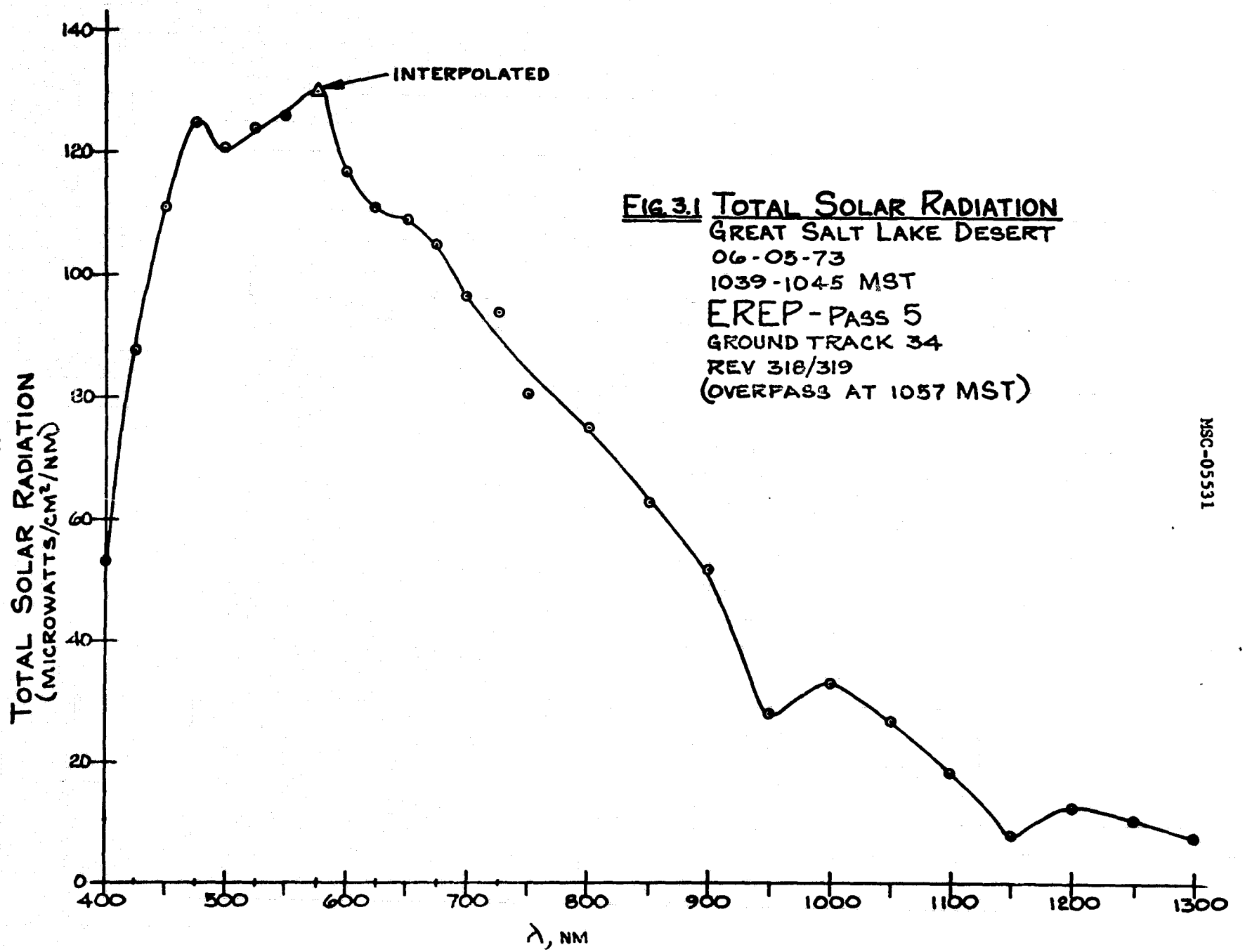


**FIG. 3.1 TOTAL SOLAR RADIATION**
GREAT SALT LAKE DESERT
06-05-73
1039-1045 MST
EREP - PASS 5
GROUND TRACK 34
REV 318/319
(OVERPASS AT 1057 MST)

MSC-05531

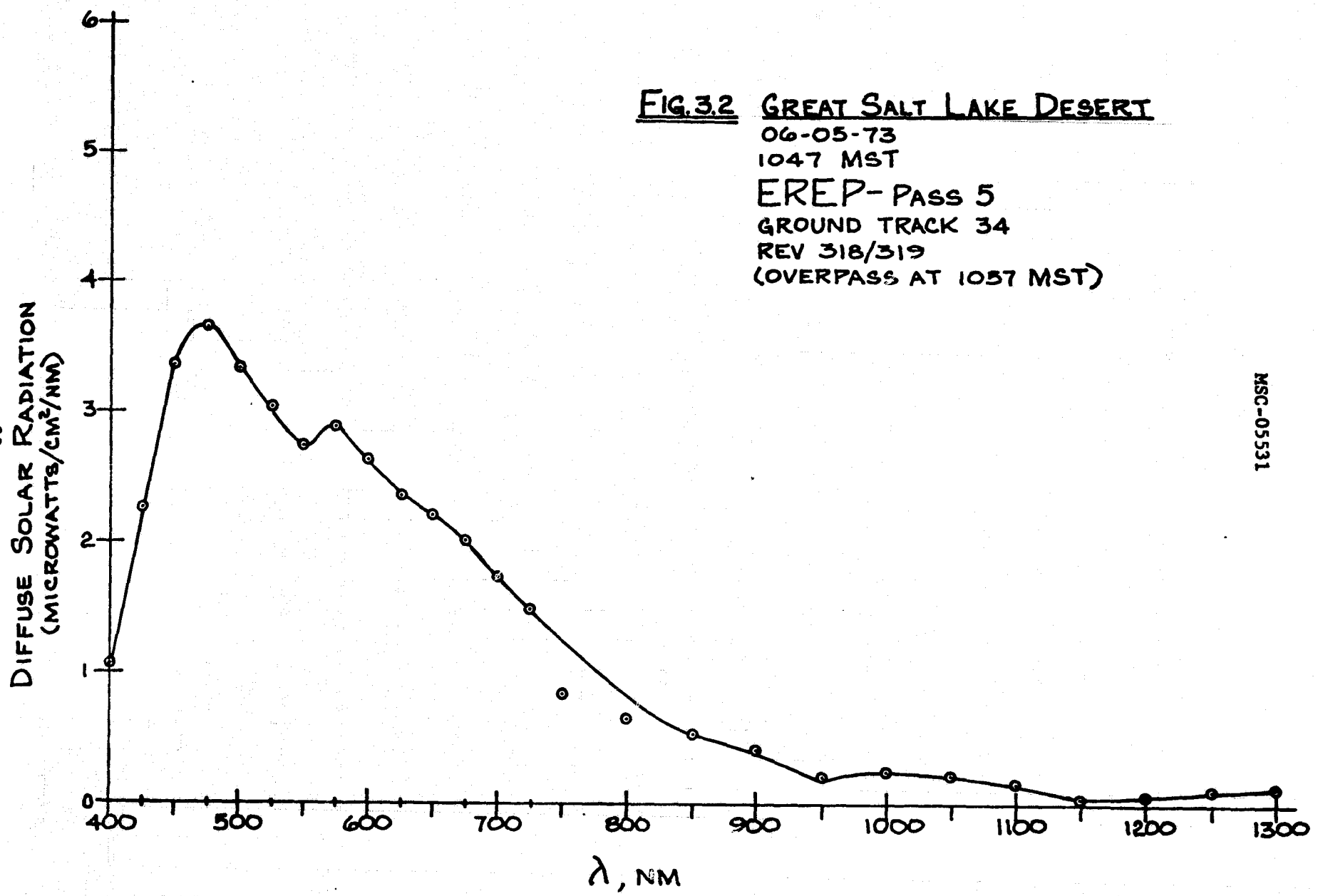


FIG. 3.2 GREAT SALT LAKE DESERT
06-05-73
1047 MST
EREP - PASS 5
GROUND TRACK 34
REV 318/319
(OVERPASS AT 1057 MST)

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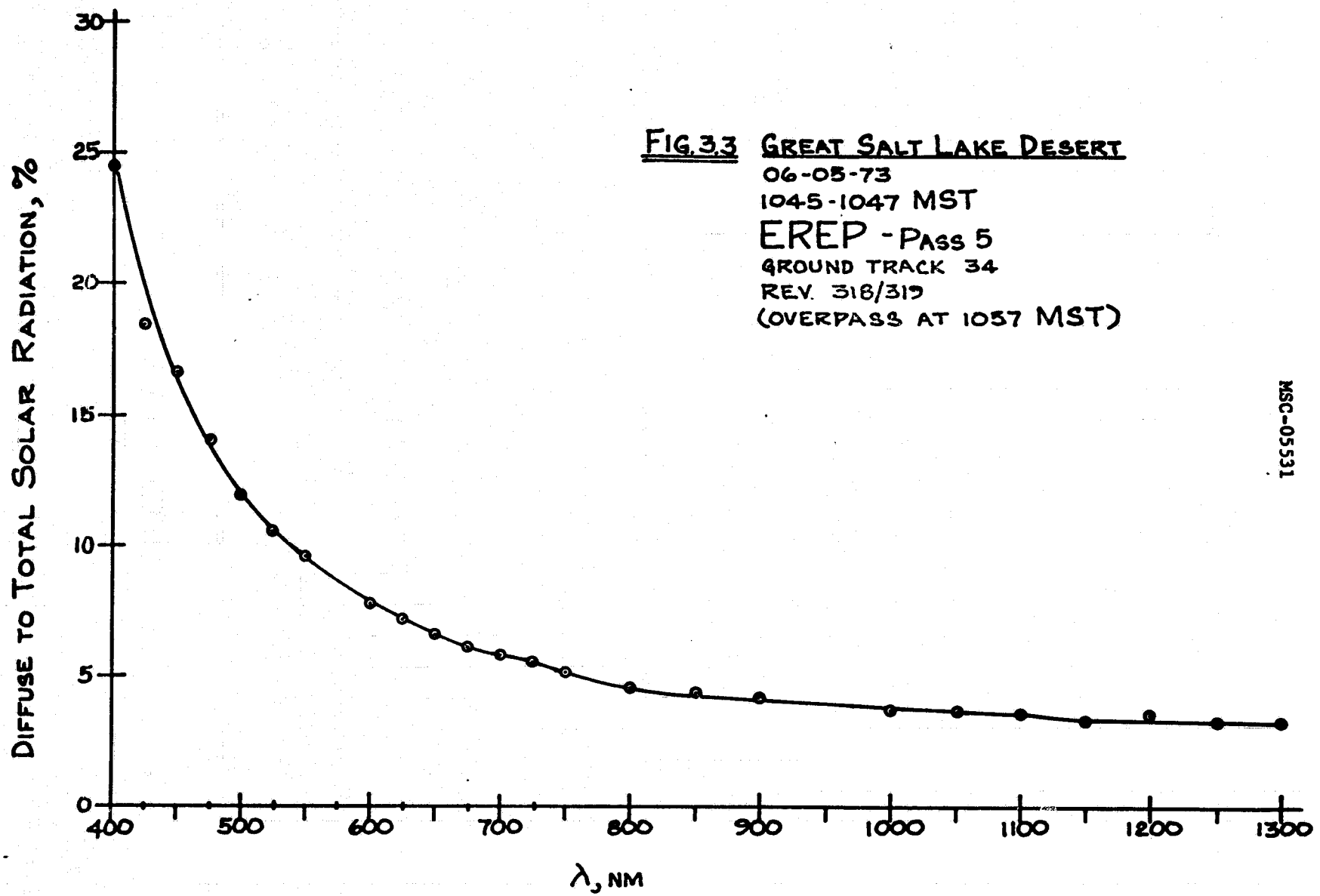



FIG. 3.3 GREAT SALT LAKE DESERT
06-05-73
1045-1047 MST
EREP - PASS 5
GROUND TRACK 34
REV. 318/319
(OVERPASS AT 1057 MST)

MSC-05531

### 3.2.1.2 Atmospheric Optical Depth

The atmospheric optical depth was determined by making measurements of the direct solar beam as a function of atmospheric air mass, m. The air mass is given as sec $\Theta_o$, where $\Theta_o$ is the solar zenith angle, for angles of less than $70^o$. This was the case for all measurements. If the atmosphere is clear and stable, the output of the spectroradiometer can be plotted vs the air mass, resulting in a linear relationship, on a semi-log plot, as shown in Figures 3.4 - 3.8. This relationship can be expressed as:

$$M = M_o e^{-\tau \sec \Theta_o}$$

or

$$\ln M = -\tau \sec \Theta_o + \ln M_o$$

where M is the measured direct solar beam meter reading of the spectroradiometer, $\tau$ is the atmospheric optical depth, $M_o$ is the spectroradiometer meter reading if the direct solar beam would be measured outside of the atmosphere. Hence, it can be seen from the above equation that $-\tau$ is the slope of the curve, $M_o$ is the y axis intercept, and M and sec $\Theta_o$ are the variables.

The atmospheric optical depth, for the Great Salt Lake Desert overpass, is shown in Figure 3.9. Also shown are comparative measurements made with an Eppley photometer.

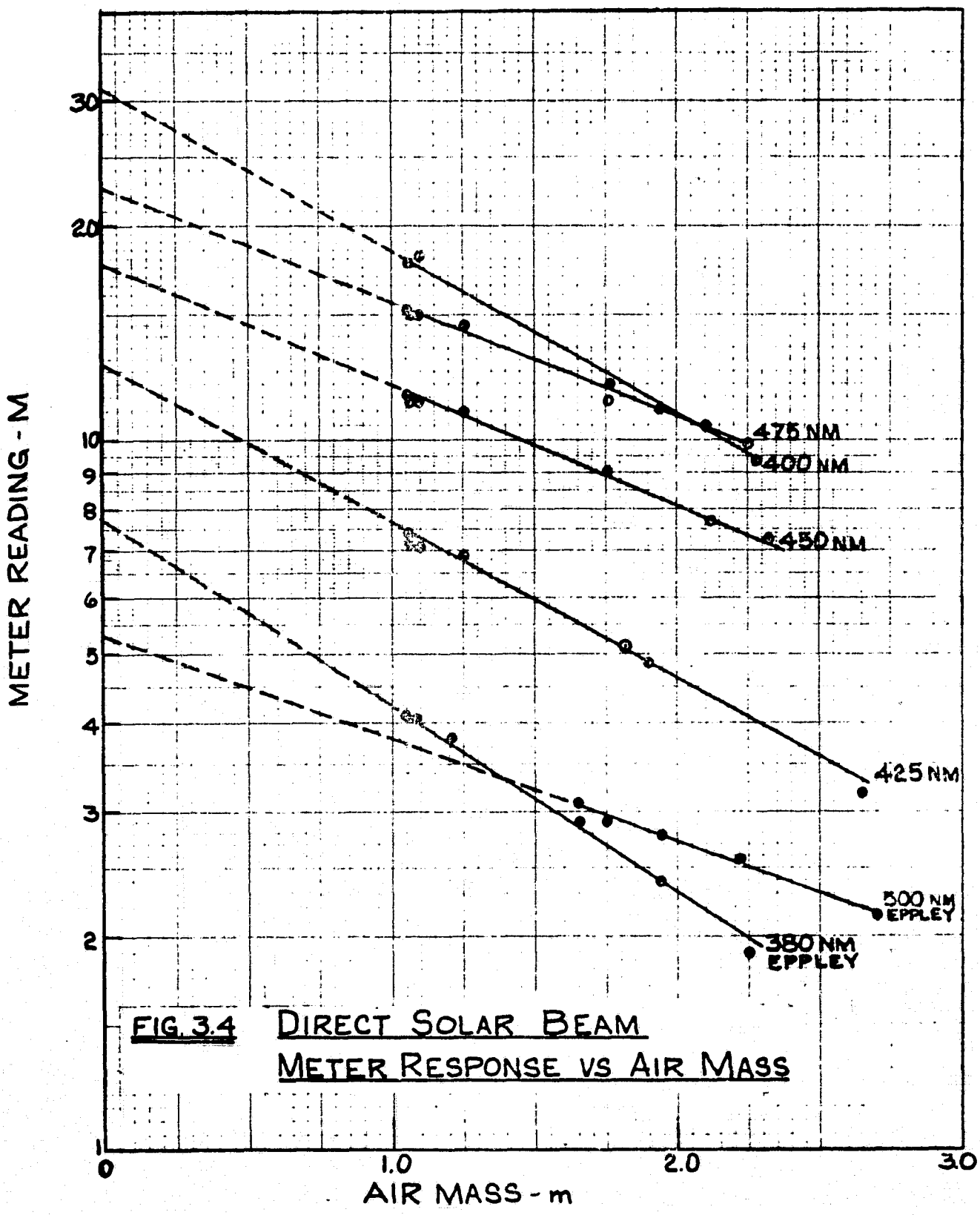



FIG. 3.4 DIRECT SOLAR BEAM METER RESPONSE VS AIR MASS

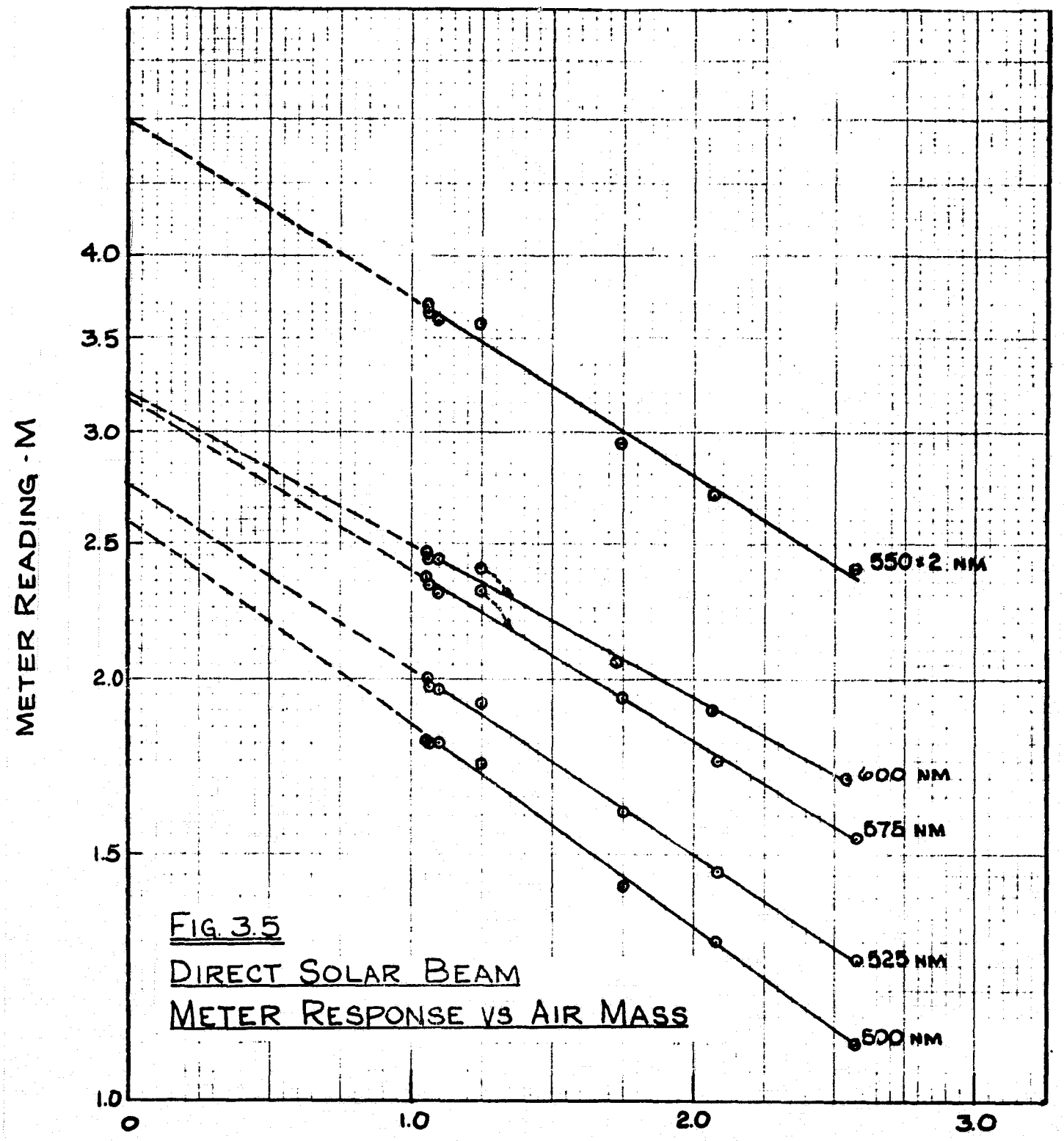



FIG. 3.5
DIRECT SOLAR BEAM
METER RESPONSE VS AIR MASS

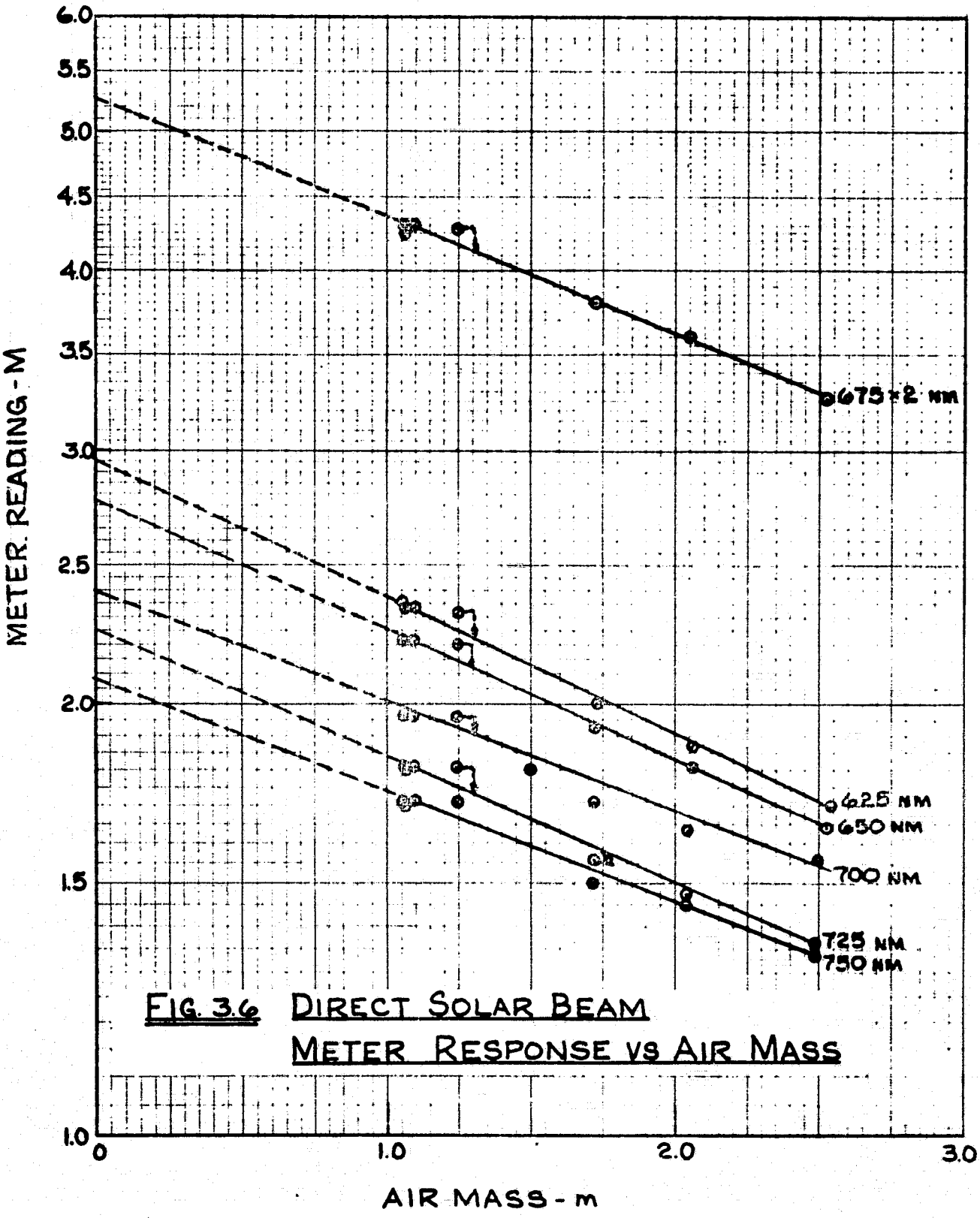



FIG. 3.6 DIRECT SOLAR BEAM METER RESPONSE VS AIR MASS

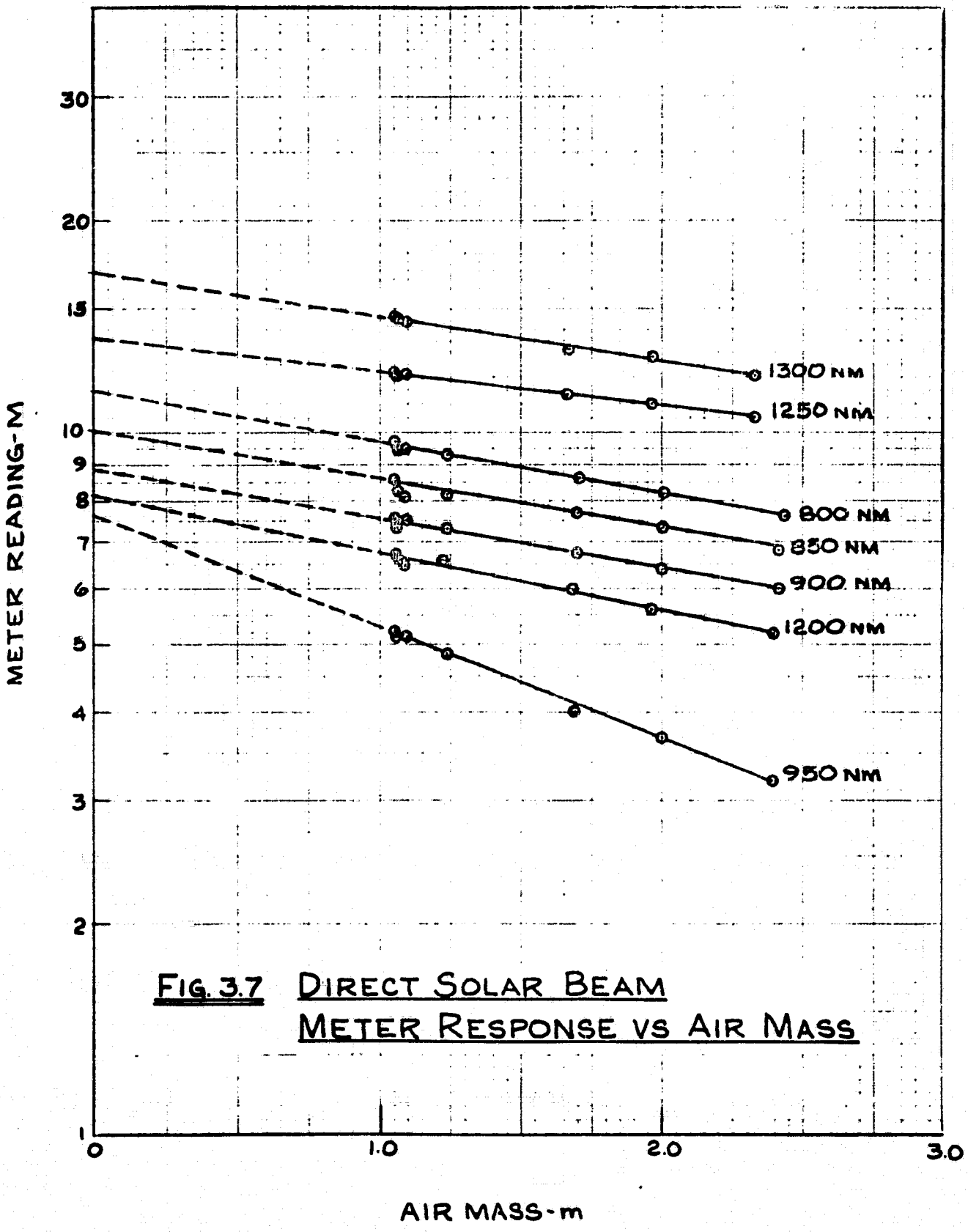



FIG. 3.7 DIRECT SOLAR BEAM METER RESPONSE VS AIR MASS

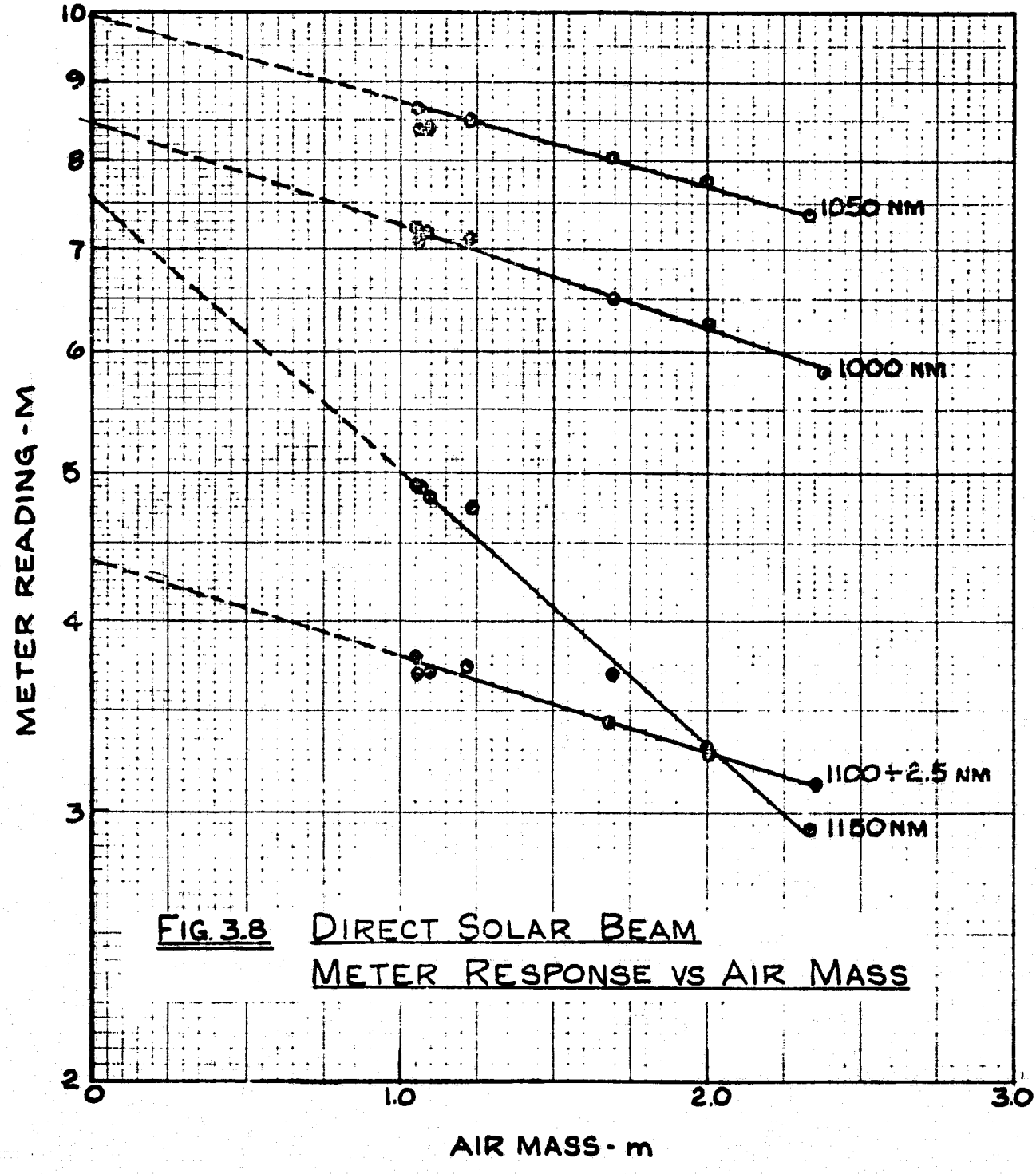



FIG. 3.8 DIRECT SOLAR BEAM METER RESPONSE VS AIR MASS

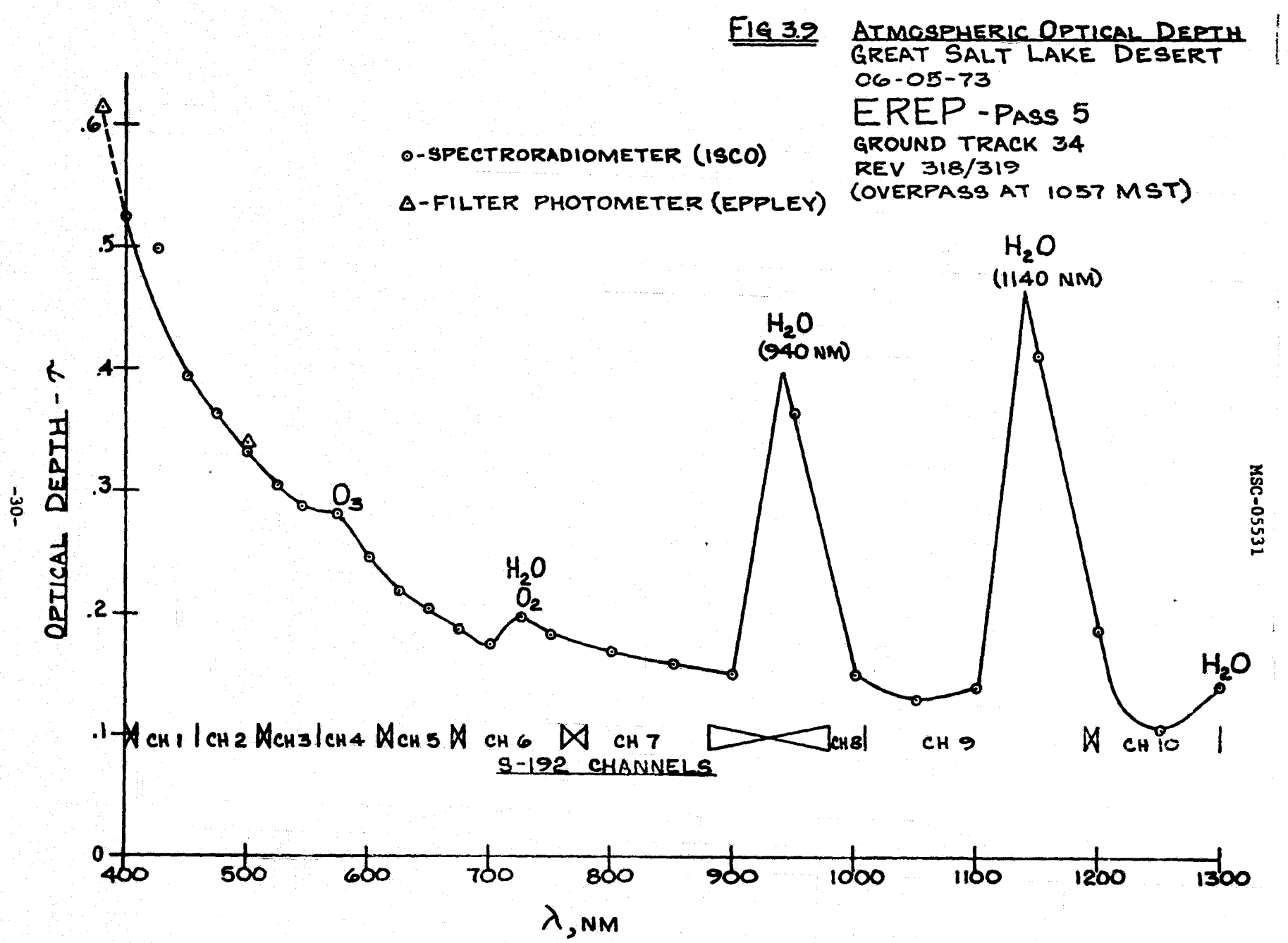


FIG 3.9 ATMOSPHERIC OPTICAL DEPTH
GREAT SALT LAKE DESERT
06-05-73
EREP - PASS 5
GROUND TRACK 34
REV 318/319
(OVERPASS AT 1057 MST)
⊙-SPECTRORADIOMETER (ISCO)
Δ-FILTER PHOTOMETER (EPPLEY)
$H_2O$ (1140 NM)
$H_2O$ (940 NM)
$O_3$
$H_2O$ $O_2$
$H_2O$
OPTICAL DEPTH - τ
.6
.5
.4
.3
.2
.1
0
CH 1 CH 2 CH 3 CH 4 CH 5 CH 6 CH 7 CH 8 CH 9 CH 10
S-192 CHANNELS
400 500 600 700 800 900 1000 1100 1200 1300
λ, NM
MSC-05531

3.2.1.3 Target Hemispherical and Directional Reflectance: The hemispherical reflectance of the target is shown in Figure 3.10. This was derived by ratioing the amount of up welling (180°) solar radiation coming from the target to the amount of incoming total (180°) solar radiation. The collecting diffuser was positioned about 6 in. above the target surface. Since the diffuser has a true cosine response, it has a selective response in terms of target area. This response is shown in Figure 3.11. It is evident that a great percentage of the up welling target radiance originates from the first few feet from directly beneath the diffuser. Hence, the hemispherical reflectance measurement is representative os such an area.

The directional reflectance of the target was measured by removing the diffuser from the end of the fiber optics probe. This resulted in a 5 in. diameter area being observed by the sensor. The target was observed normal (90°) to its surface. The reflectance was determined by measuring the radiance (not absolute) from calibrated "white" and "gray" cards; then measuring the radiance of the target. The reflectance of the target can then be determined by using the curves shown in Figures 3.12 to 3.15. The points shown on these curves correspond to the radiance measured from the cards vs their reflectance. The measurements of the target radiance can then be used to determine target reflectance.

FIG. 3.10 HEMISPHERICAL REFLECTANCE
GREAT SALT LAKE DESERT
06-05-73
1042 MST
EREP - PASS 5
GROUND TRACK 34
REV 318/319
(OVERPASS AT 1057 MST)

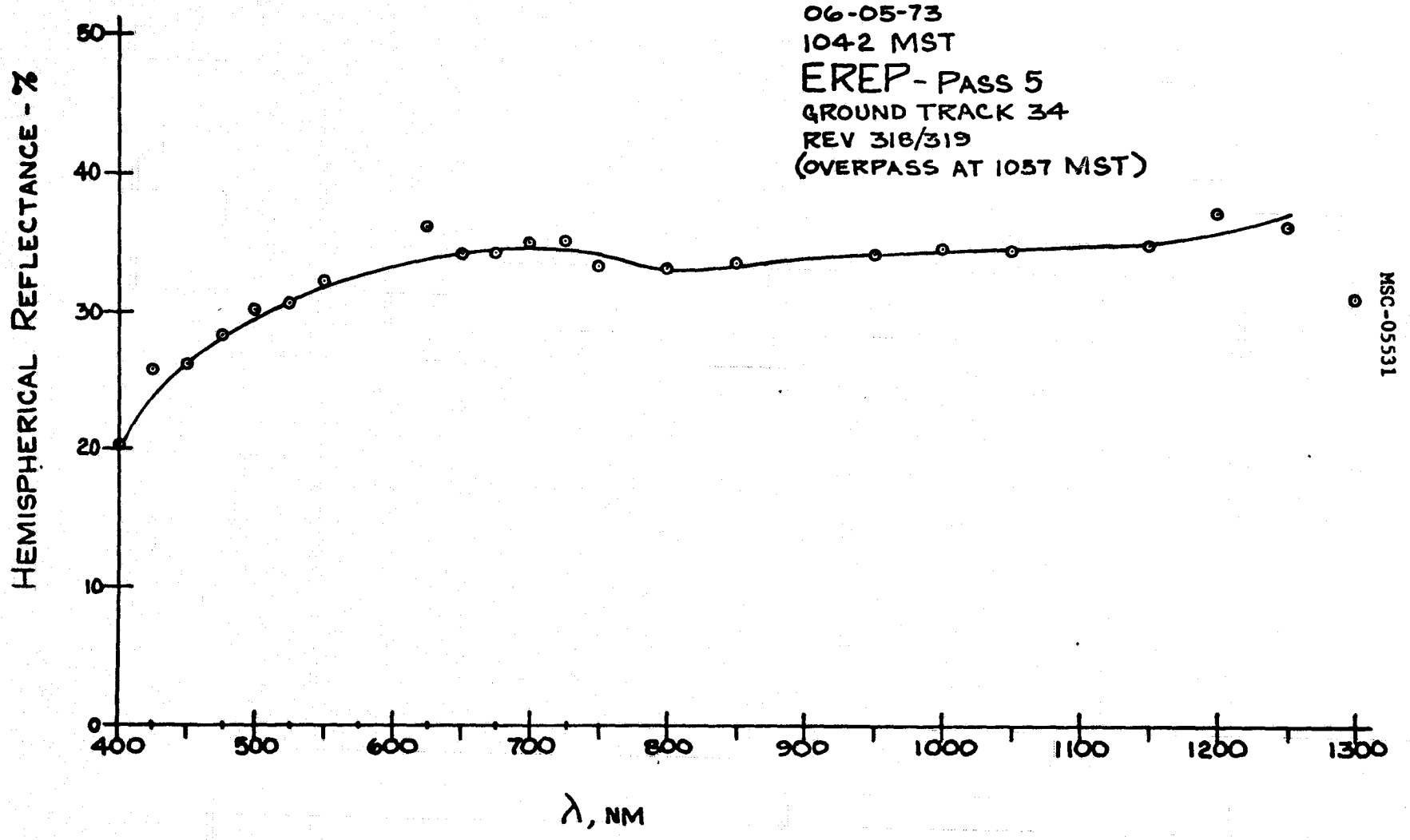
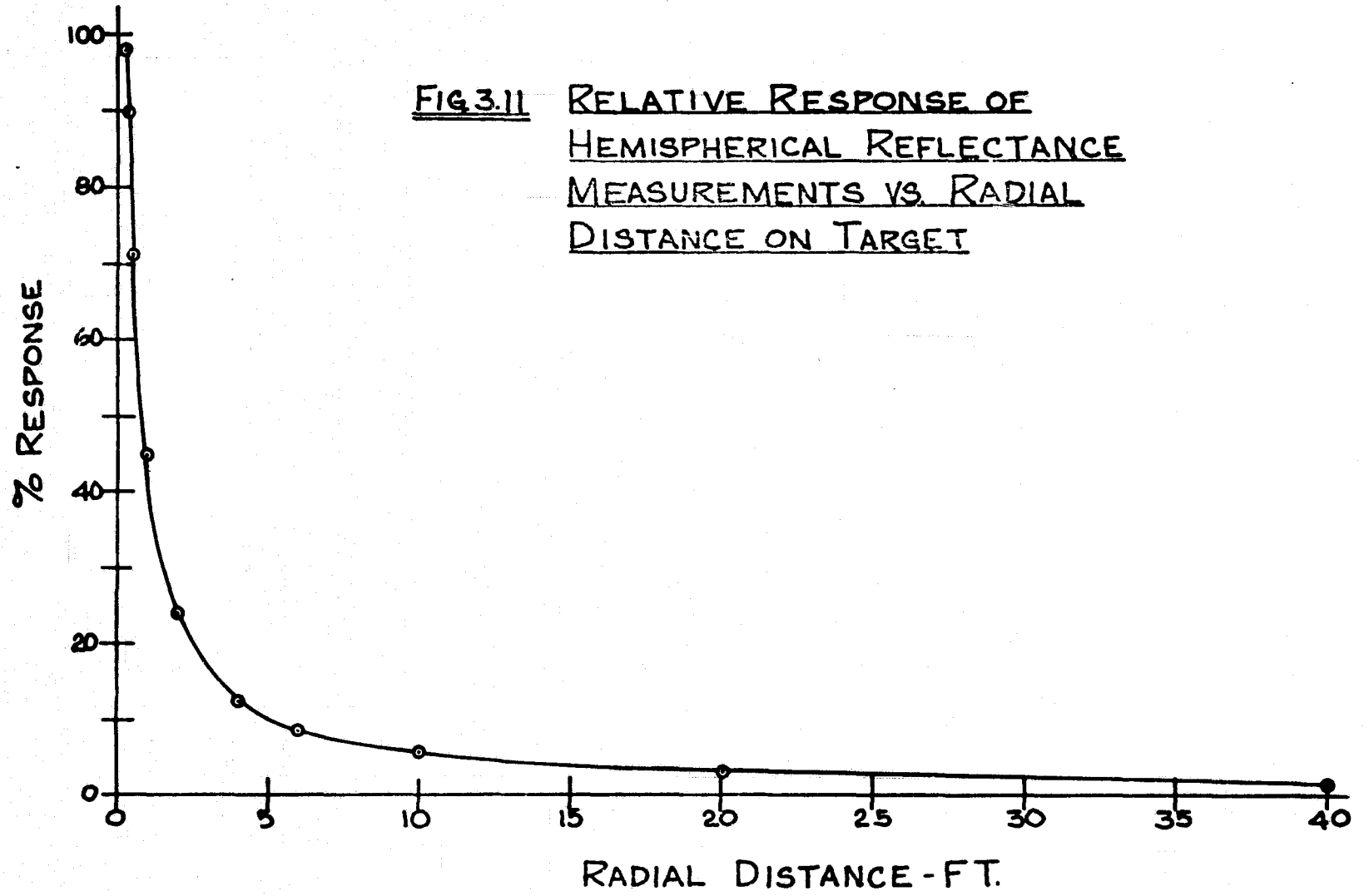


FIG 3.11 RELATIVE RESPONSE OF HEMISPHERICAL REFLECTANCE MEASUREMENTS VS. RADIAL DISTANCE ON TARGET



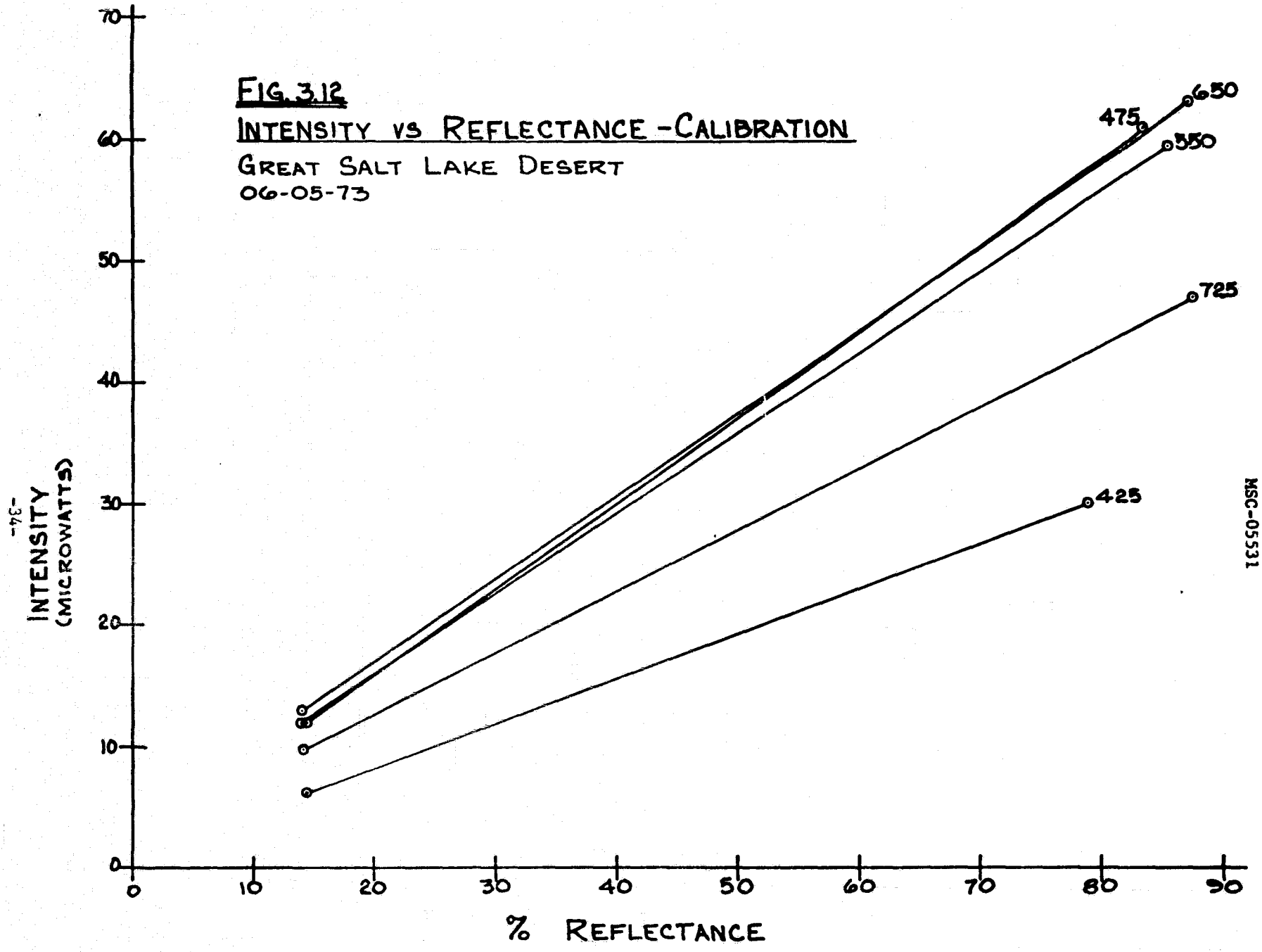


FIG. 3.12
INTENSITY VS REFLECTANCE - CALIBRATION
GREAT SALT LAKE DESERT
06-05-73
650
475
550
725
425
INTENSITY (MICROWATTS)
% REFLECTANCE
0
10
20
30
40
50
60
70
80
90
MSC-05531

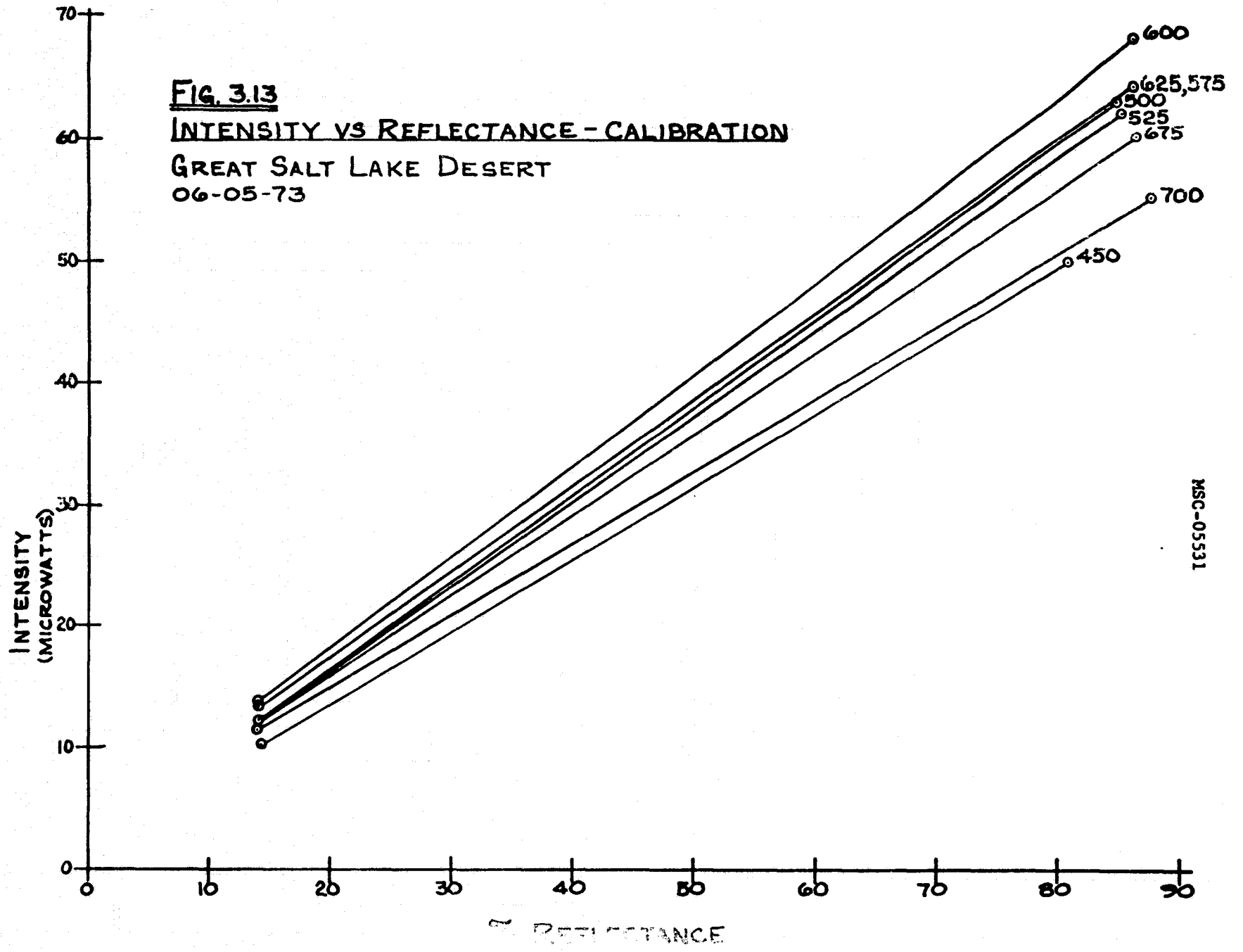


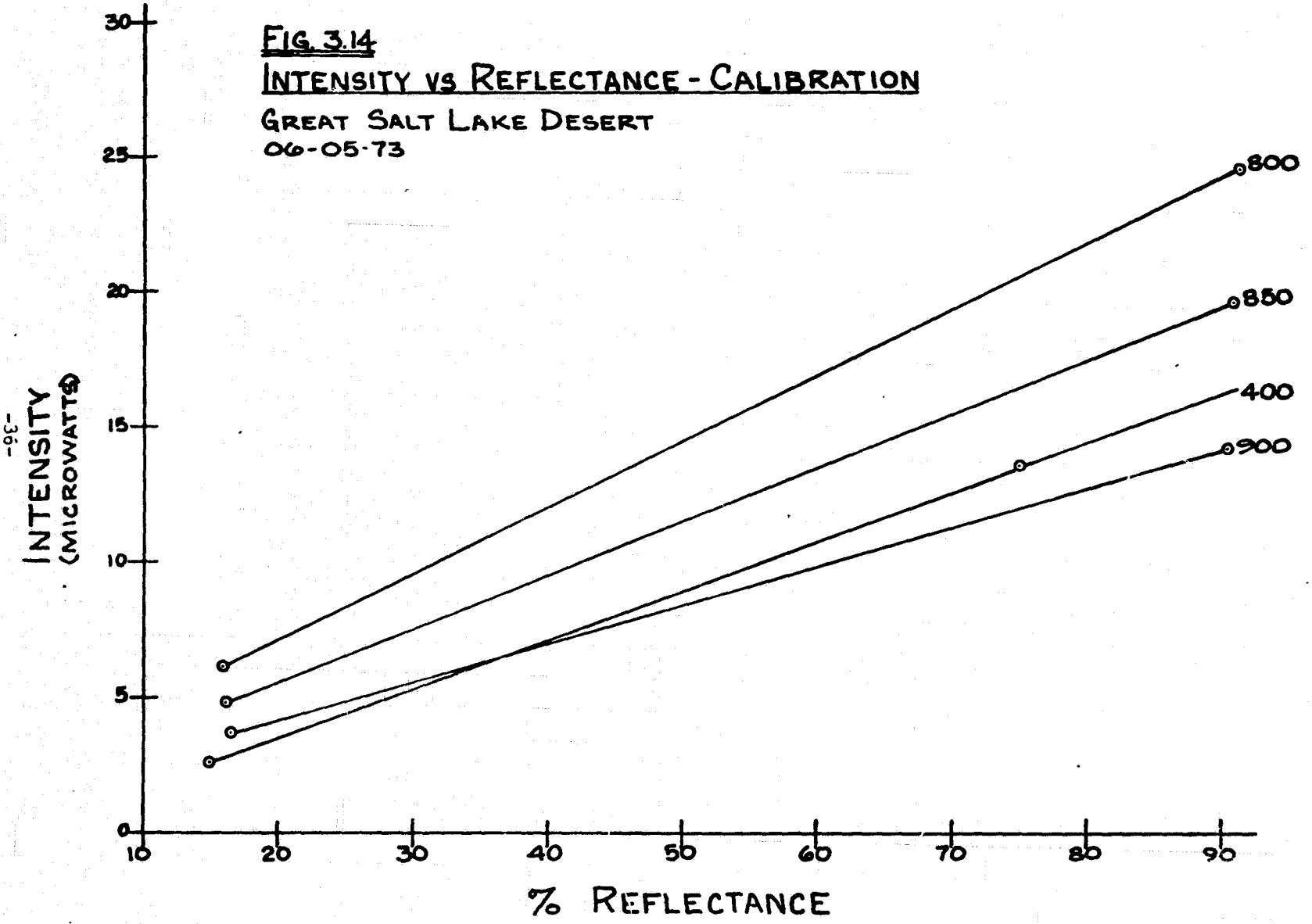
FIG. 3.13
INTENSITY VS REFLECTANCE - CALIBRATION
GREAT SALT LAKE DESERT
06-05-73
600
625,575
500
525
675
700
450
INTENSITY (MICROWATTS)
% REFLECTANCE
0
10
20
30
40
50
60
70
80
90
MSC-05531

FIG. 3.14

INTENSITY VS REFLECTANCE - CALIBRATION

GREAT SALT LAKE DESERT

06-05-73




MSC-05531

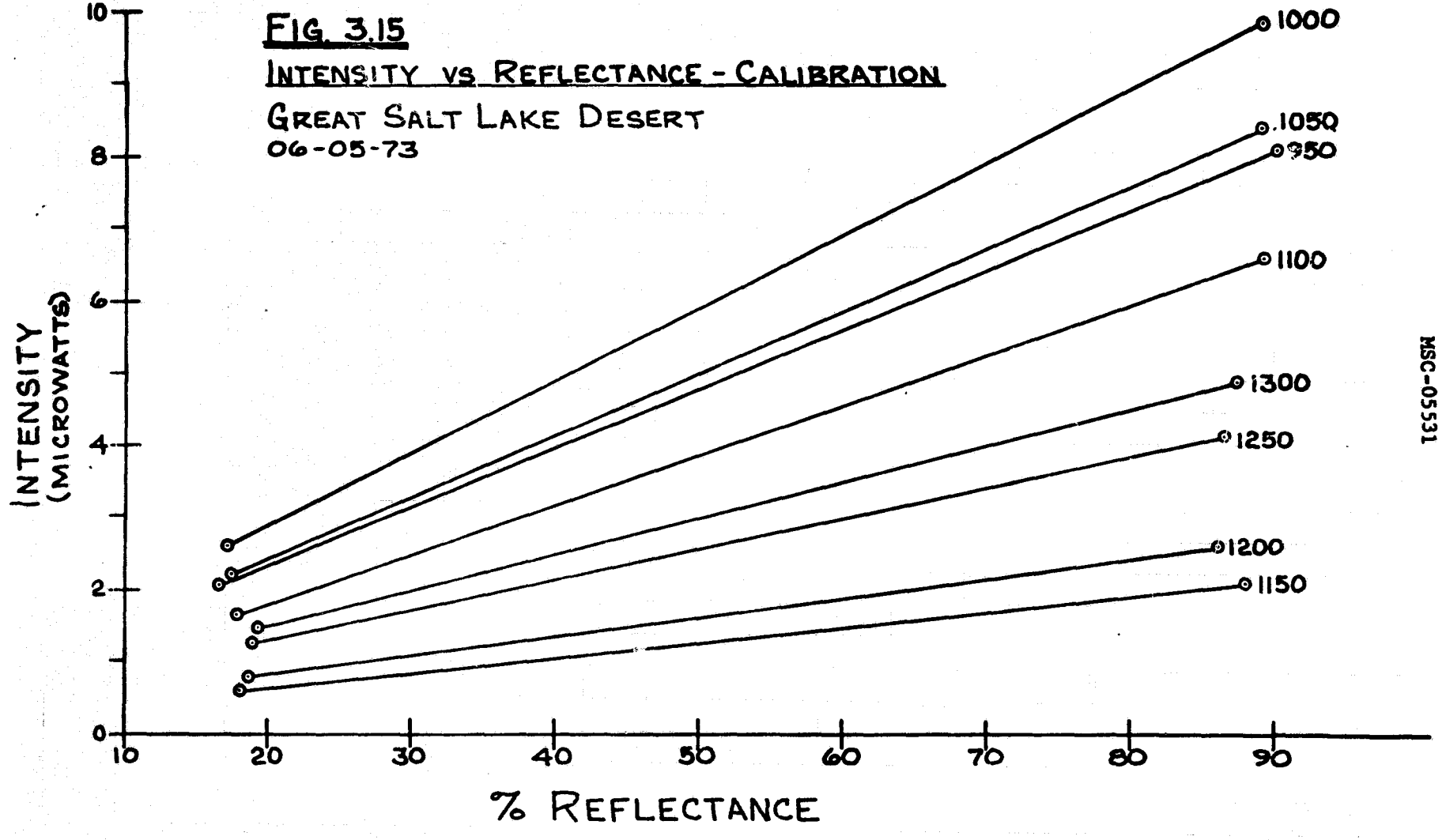


FIG. 3.15
INTENSITY VS REFLECTANCE - CALIBRATION
GREAT SALT LAKE DESERT
06-05-73
1000
1050
950
1100
1300
1250
1200
1150
INTENSITY (MICROWATTS)
% REFLECTANCE
0
2
4
6
8
10
10
20
30
40
50
60
70
80
90

MSC-05531

The resultant target reflectance is shown in Figure 3.16. The card calibrations are shown in Figure 3.17.

As with the total and diffuse measurements, several measurements of hemispherical and directional measurements were made prior to and following the overpass. The measurements were overviewed for repeatibility/precision, and then the one(s) nearest to overpass were fully analyzed.

3.2.1.4 Near Surface Meteorology

Wet bulb temperature -54°F

Dry bulb temperature -73°F

Wind speed - 4 to 8 m.p.h.

Wind Direction - WSW

Pressure - 26.0 in of Hg.

3.2.1.5 General Conditions

Completely cloud free conditions existed throughout all data taking. Atmospheric conditions could be considered as "hazy". A resident of the general area commented that "it was hazy" compared to other clear days.

The target surface appeared to be fairly uniform with an occasional small white spot, caused by salt precipitation. The surface measured extended for approximately .5 mile in the north-south direction, and approximately .8 mile in the east-west direction. Within this area, little or no vegetation was present. The location of the target area is shown in Figure 3.18.

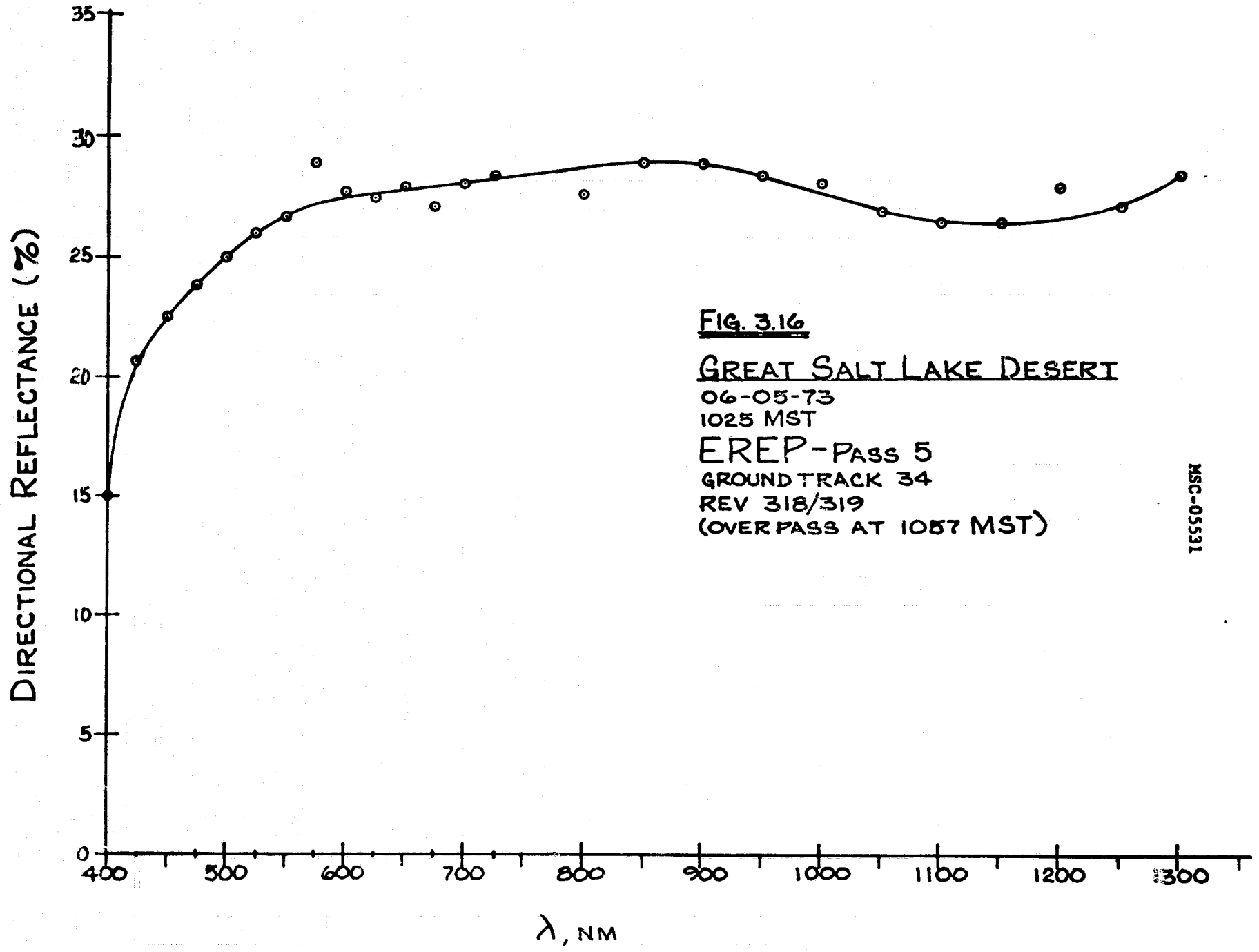
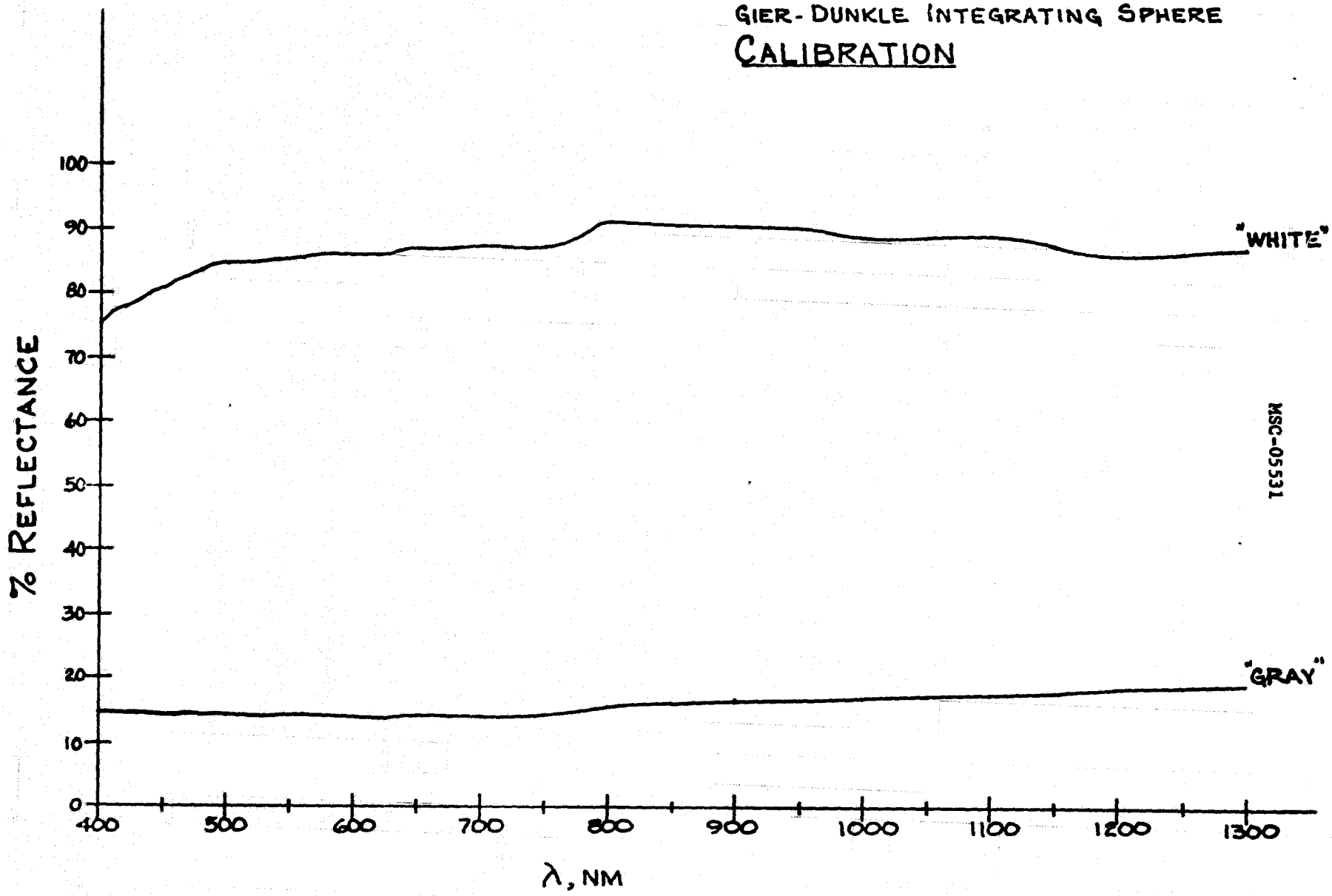



FIG. 3.16

GREAT SALT LAKE DESERT
06-05-73
1025 MST
EREP-PASS 5
GROUND TRACK 34
REV 318/319
(OVER PASS AT 1057 MST)

MSC-05531

FIG. 3.17 REFLECTANCE STANDARDS
("WHITE" AND "GRAY" CARDS)
BECKMAN DK-2A
GIER-DUNKLE INTEGRATING SPHERE
CALIBRATION



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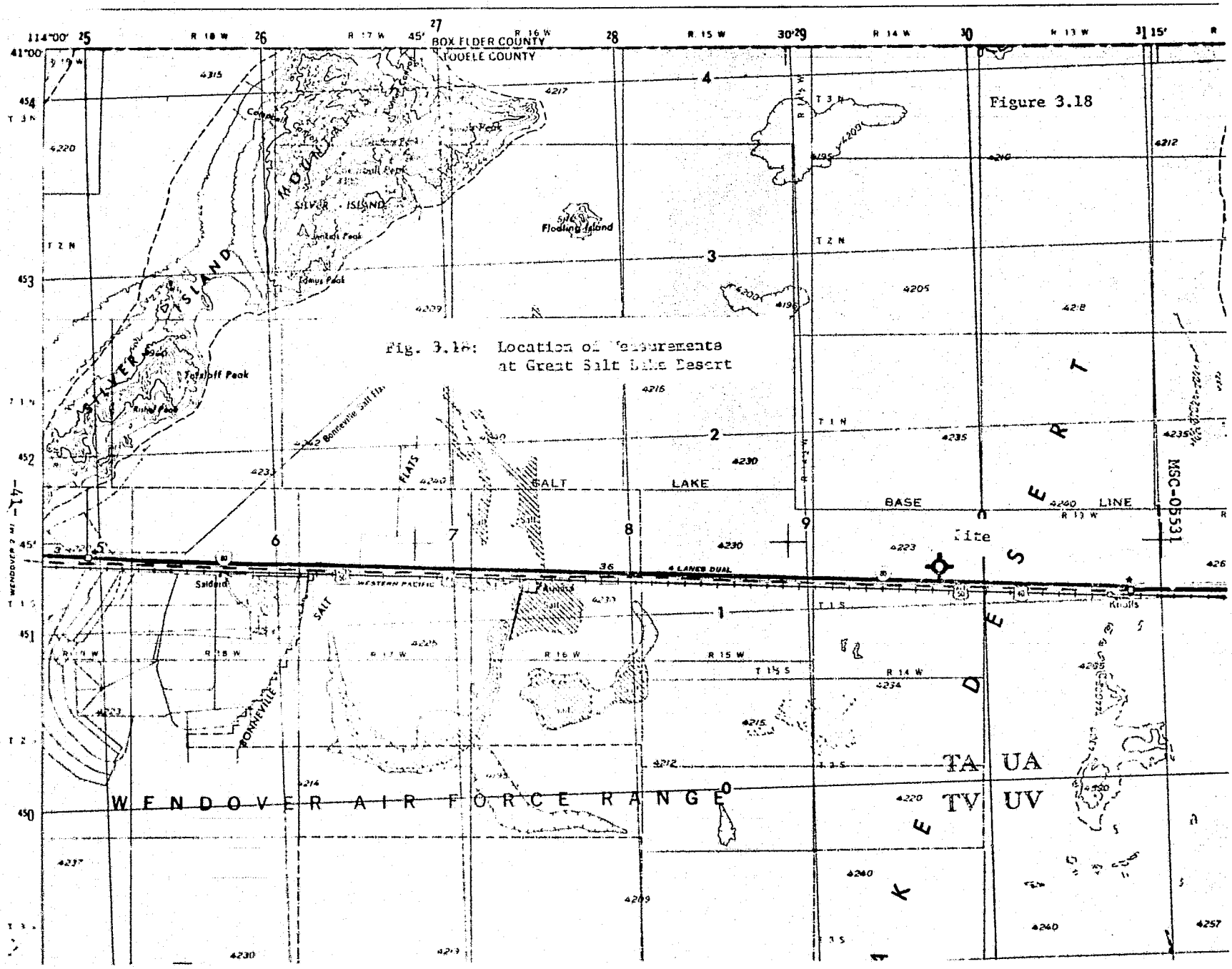



Figure 3.18

Fig. 3.18: Location of Measurements at Great Salt Lake Desert

3.2.2 Wilcox Playa, Arizona

Date: 07 Jun 1973

EREP Pass: 3, Ground Track 6; Rev. 290/291

Time of Overpass: 154:19:26:27 GMT

3.2.2.1 Total and Diffuse Solar Radiation

The absolute quantity of total solar radiation, near time of overflight, is shown in Figure 3.19. It was not possible to obtain measurements of the diffuse solar radiation because of intermittent shadowing caused by small cumulus clouds. In order to assure that the total measurement was indeed representative of conditions, two separate measurements were analyzed (1213 and 1230 MST) and compared. As shown in Figure 3.19; the measurements are quite consistent.

3.2.2.2 Atmospheric Optical Depth

Ground observations indicated a definite haze layer existing over the Playa area during early morning and cumulus build up. The unstable conditions are shown in Figure 3.20. It is evident that the optical depth was a function of time and it was quite variable; unlike the stable conditions at the Great Salt Lake Desert reported in the preceeding sections.

The atmospheric optical depth, near the time of overpass, can be derived by

$$\tau = \frac{\ln M_o - \ln M}{\sec \theta_o}$$

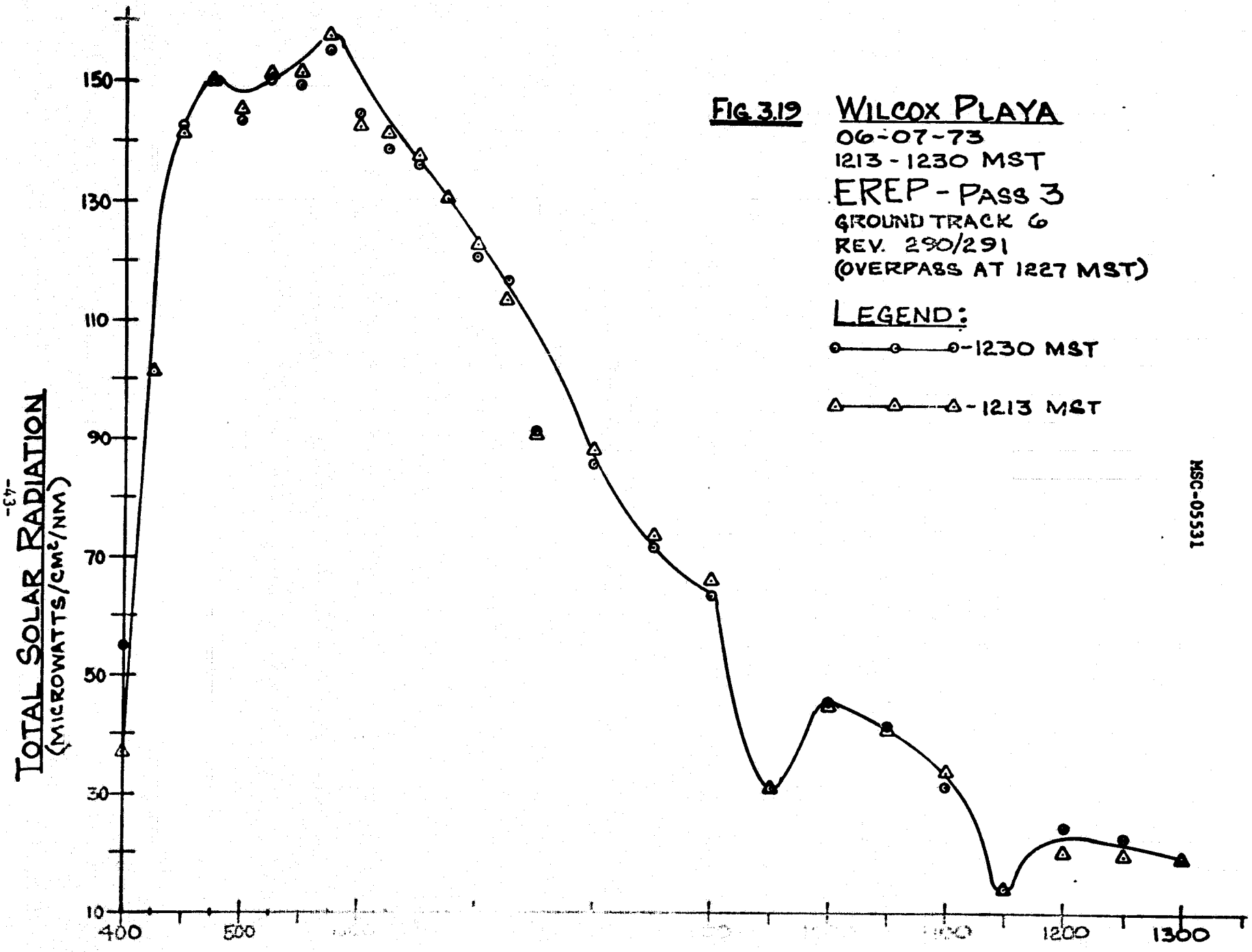


FIG. 3.19 WILCOX PLAYA
06-07-73
1213 - 1230 MST
EREP - PASS 3
GROUND TRACK 6
REV. 290/291
(OVERPASS AT 1227 MST)
LEGEND:
-1230 MST
-1213 MST
TOTAL SOLAR RADIATION
(MICROWATTS/CM²/NM)
150
130
110
90
70
50
30
10
400
500
1200
1300
MSC-05531

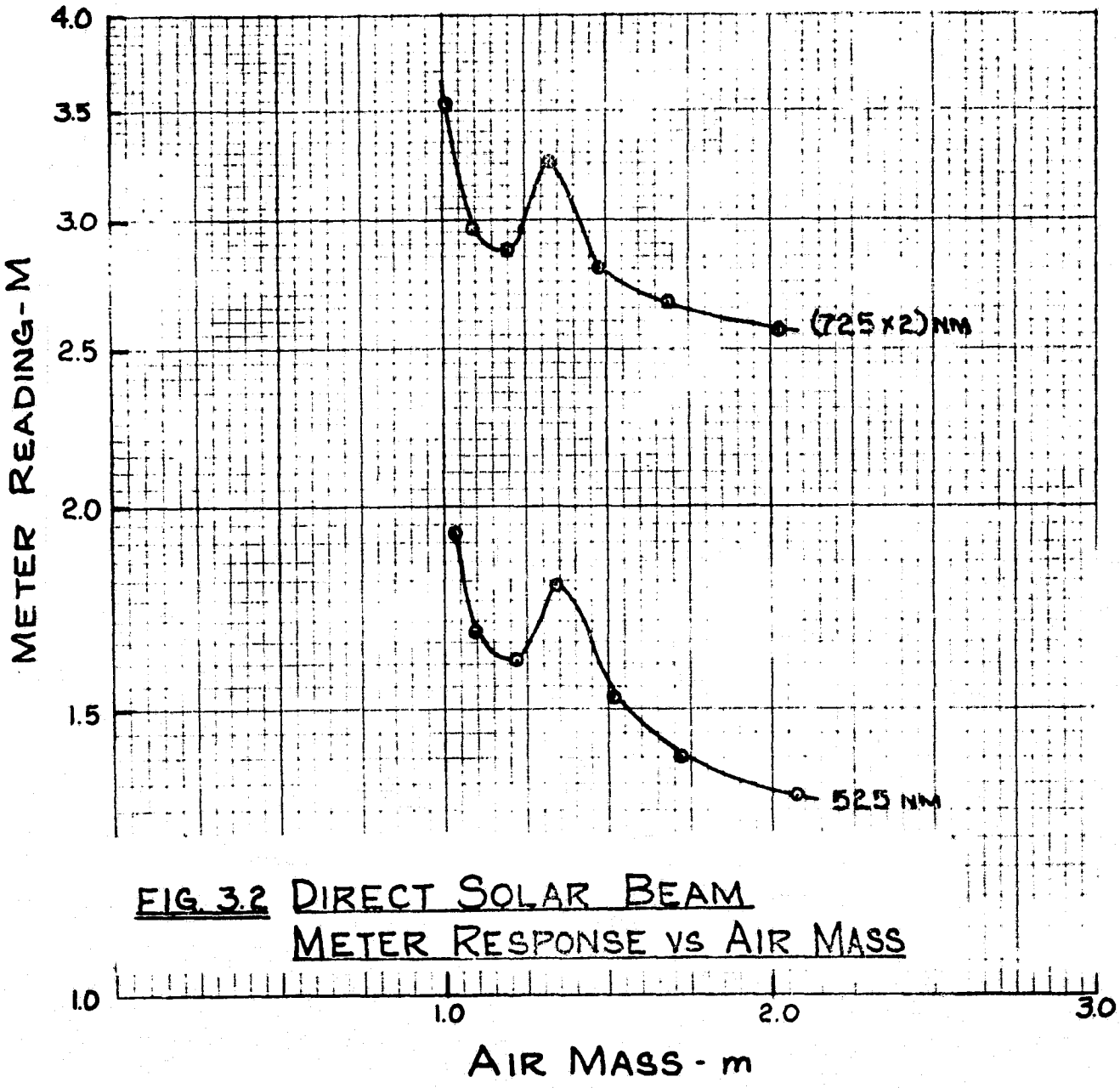



FIG. 3.2 DIRECT SOLAR BEAM METER RESPONSE VS AIR MASS

where $M_o$ is taken from the Great Salt Lake Desert analysis (Figures 3.4 to 3.8). The results are shown in Figure 3.21.

3.2.2.3 Target Hemispherical and Directional Reflectance

The hemispherical and directional reflectance of the target were derived in the manner discussed in 3.2.1.3. However, the intermittant shadowing resulted in an incomplete directional reflectance determination. The target hemispherical reflectance is shown in Figure 3.22. The partial directional reflectance is shown in Figure 3.23, along with the corresponding hemispherical reflectance. It is evident that the target is of sufficient uniformity that the two types of reflectance are similar. The directional reflectance vs intensity is shown in Figures 3.24 and 3.25. The calibrated cards, as shown in Figure 3.17, were used at Wilcox Playa also.

3.2.2.4 Near Surface Meteorology

Wet Bulb Temperature - 58°F

Dry Bulb Temperature - 80°F

Wind Speed - 6 m.p.h.

Wind Direction - WSW

Pressure - 25.80 in of Hg.

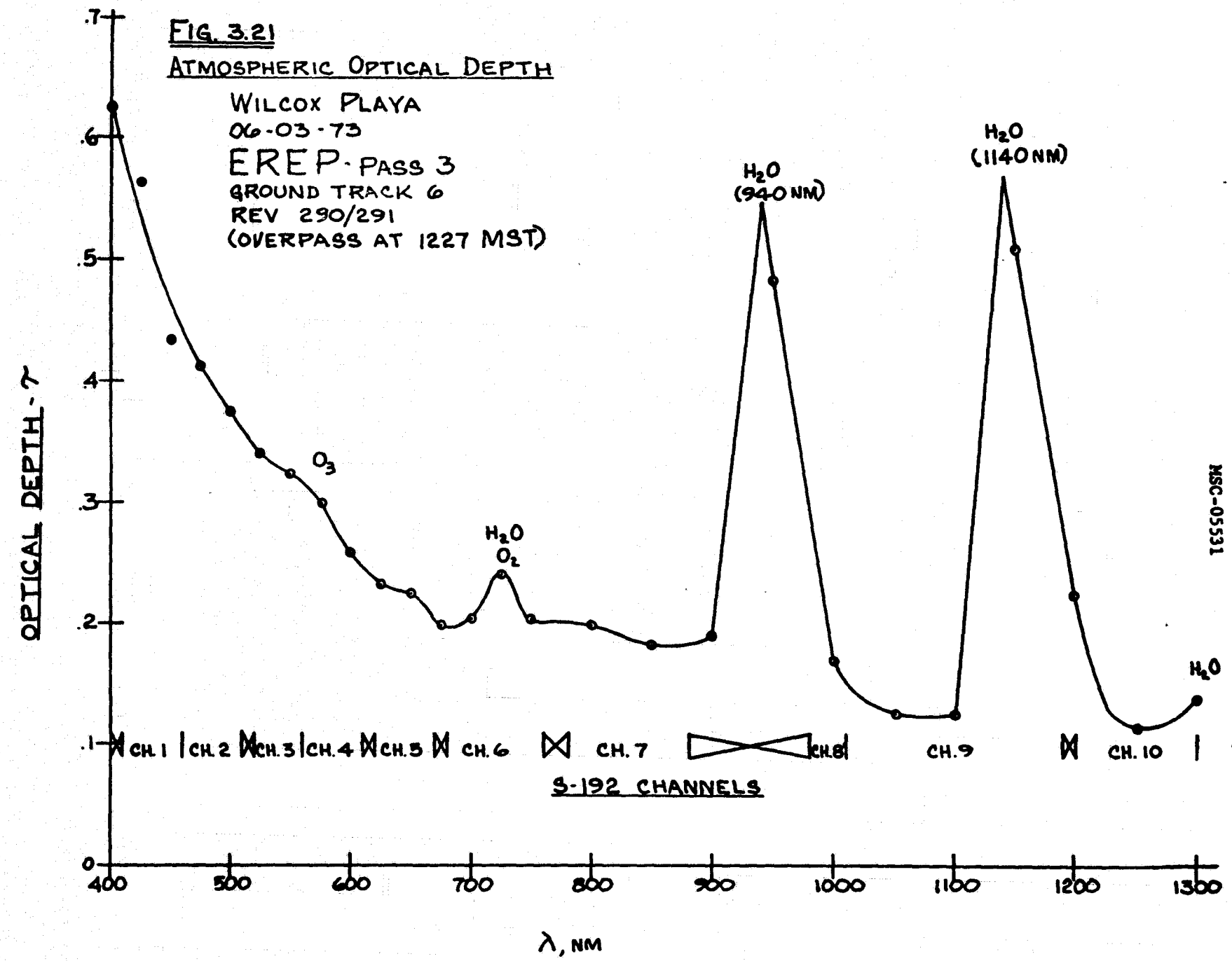


FIG. 3.21
ATMOSPHERIC OPTICAL DEPTH
WILCOX PLAYA
06-03-73
EREP - PASS 3
GROUND TRACK 6
REV 290/291
(OVERPASS AT 1227 MST)
OPTICAL DEPTH - τ
λ, NM
O3
H2O
O2
H2O
(940 NM)
H2O
(1140 NM)
H2O
CH. 1
CH. 2
CH. 3
CH. 4
CH. 5
CH. 6
CH. 7
CH. 8
CH. 9
CH. 10
S-192 CHANNELS
MSC-05531

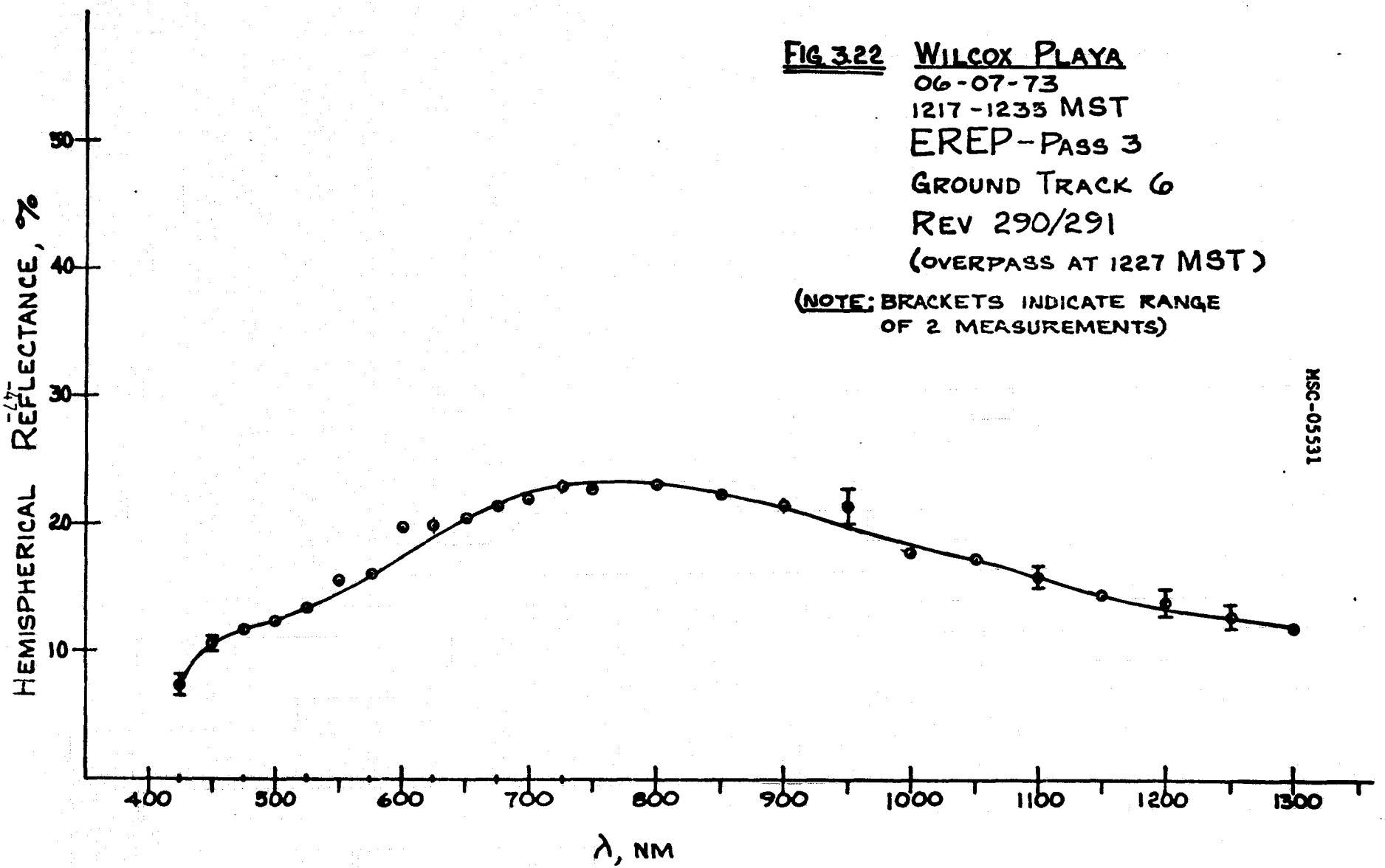


FIG 3.22 WILCOX PLAYA
06-07-73
1217-1235 MST
EREP-PASS 3
GROUND TRACK 6
REV 290/291
(OVERPASS AT 1227 MST)
(NOTE: BRACKETS INDICATE RANGE OF 2 MEASUREMENTS)
MSC-05531
HEMISPHERICAL REFLECTANCE, %
50
40
30
20
10
400
500
600
700
800
900
1000
1100
1200
1300
λ, NM

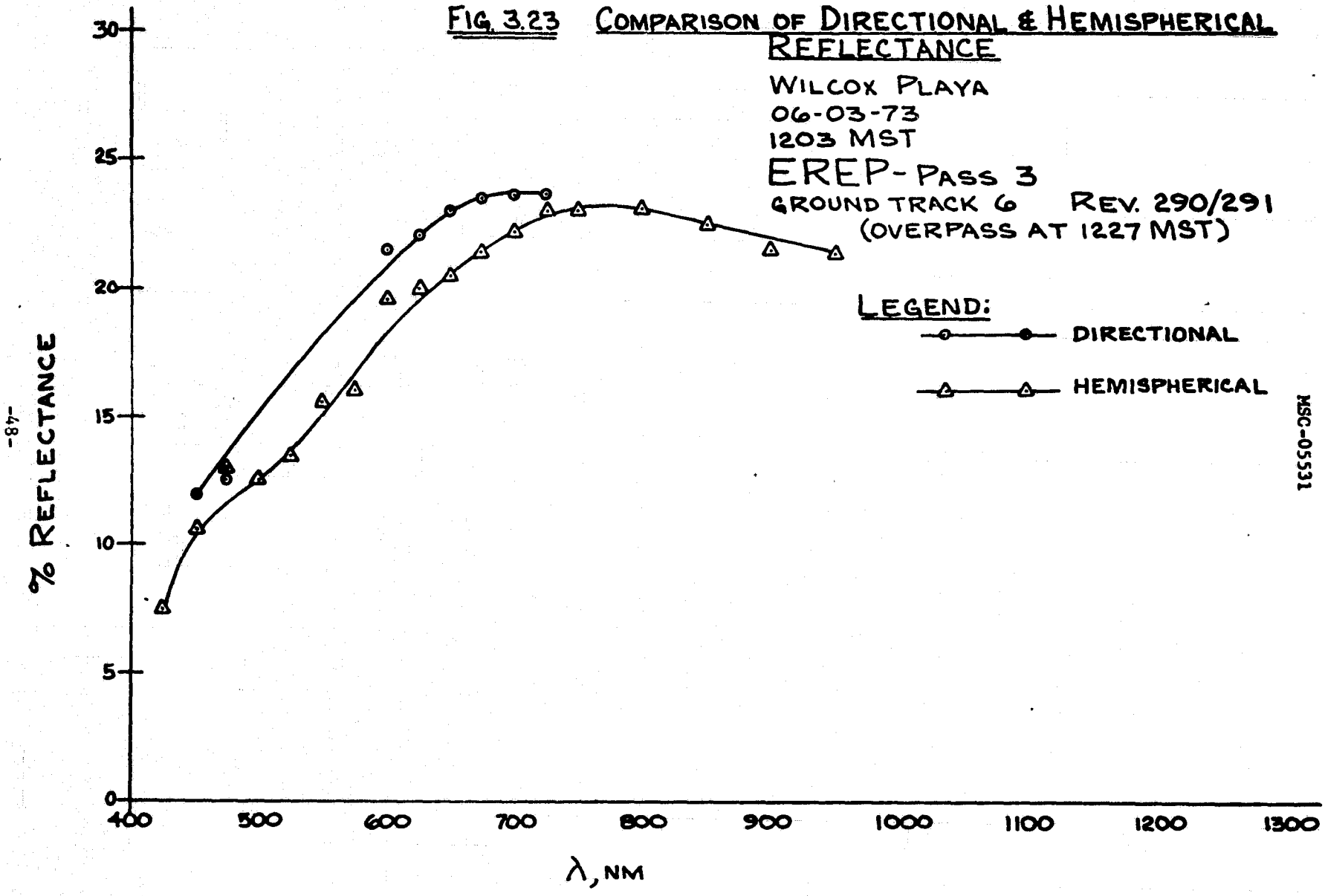


FIG. 3.23 COMPARISON OF DIRECTIONAL & HEMISPHERICAL REFLECTANCE
WILCOX PLAYA
06-03-73
1203 MST
EREP - PASS 3
GROUND TRACK 6 REV. 290/291
(OVERPASS AT 1227 MST)
LEGEND:
DIRECTIONAL
HEMISPHERICAL
% REFLECTANCE
λ, NM
0
5
10
15
20
25
30
400
500
600
700
800
900
1000
1100
1200
1300
MSC-05531

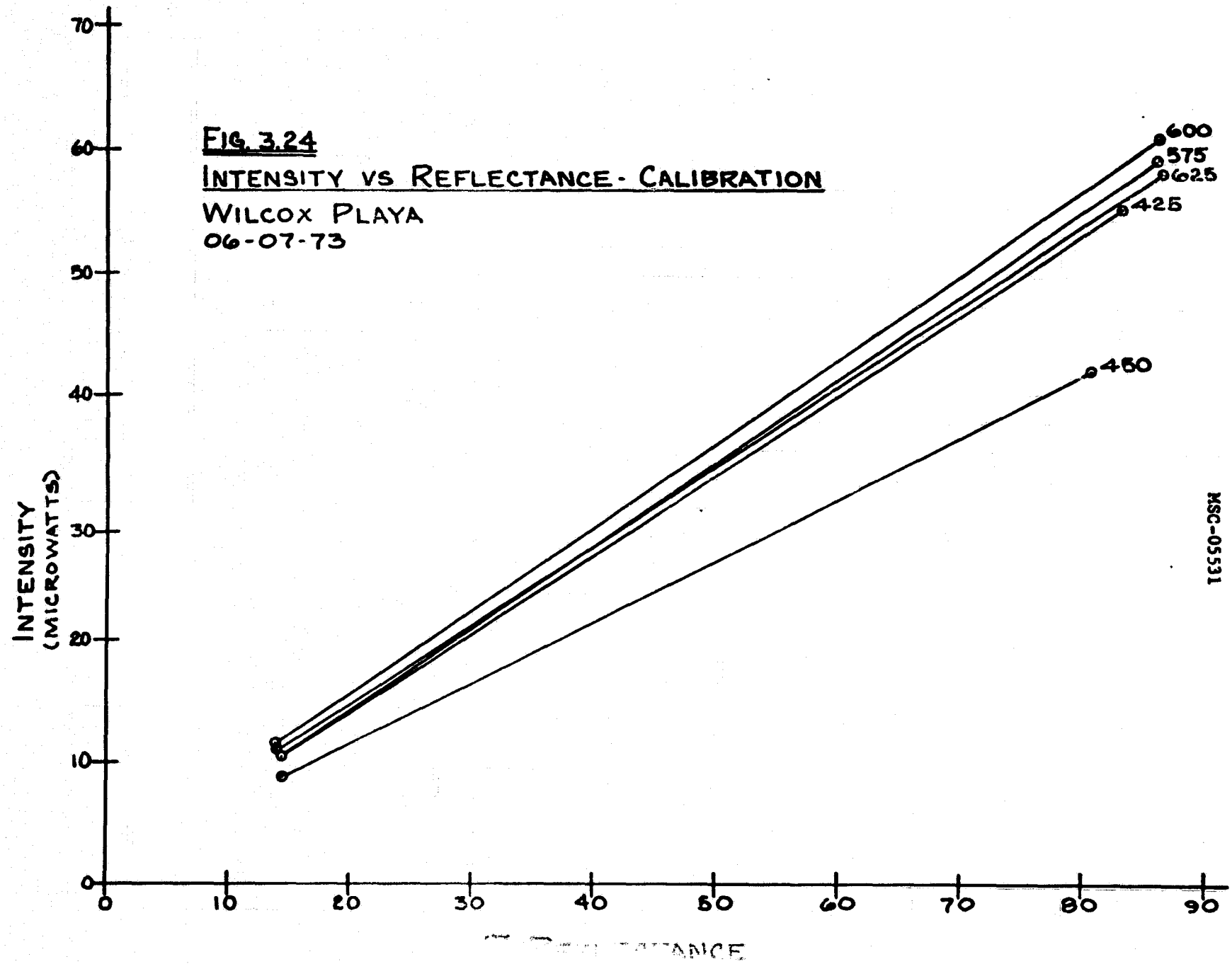


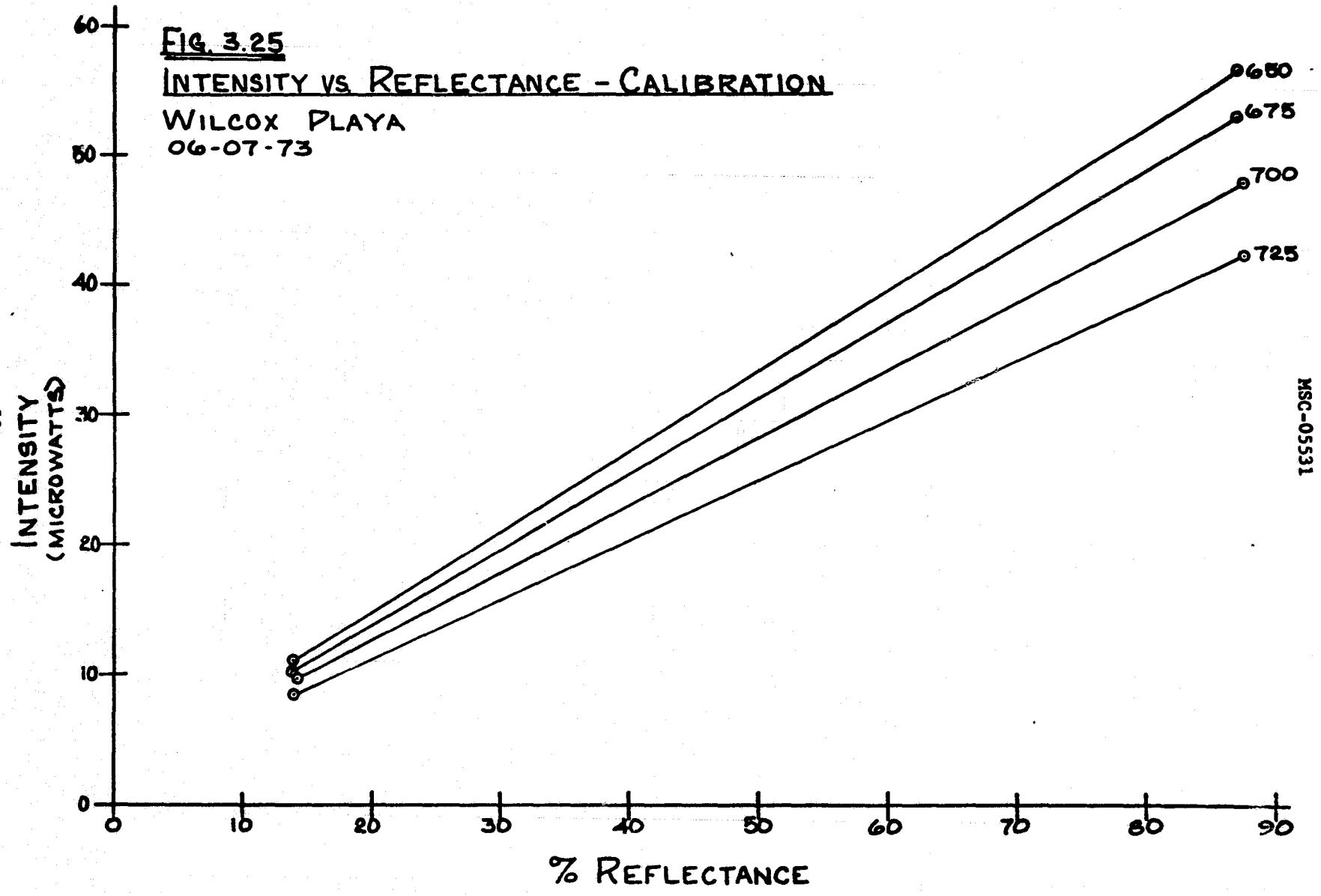
FIG. 3.24
INTENSITY VS REFLECTANCE - CALIBRATION
WILCOX PLAYA
06-07-73
600
575
625
425
450
INTENSITY (MICROWATTS)
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
MSC-05531

FIG. 3.25

INTENSITY VS REFLECTANCE - CALIBRATION

WILCOX PLAYA

06-07-73

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3.2.2.5 General Conditions

As discussed previously, a definite haze layer existed over the playa area during early morning (0730 - 0900 MST). This was followed by buildup of small, scattered cumulus clouds that caused intermittant shadowing of the playa.

The playa appeared, both from the ground and from the air, to be an extremely uniform surface. The site is shown in Fig. 3.26.

3.2.3 Independence Pass, Colorado

Date: 11 Jun 1973

EREP Pass: 8, Ground Track 218, Rev. 403/404

Time of Overpass: 162:15:16:38 GMT

3.2.3.1 Total and Diffuse Solar Radiation, Target Reflectance and Optical Depth - It was originally thought ("EREP Ground Truth Data Summary, Martin Marietta Denver") that the solar radiation and reflectance data could be processed despite presence of high cirrus clouds during the overpass. However, detailed inspection indicates variances large enough to make any detailed analysis of the data illogical.

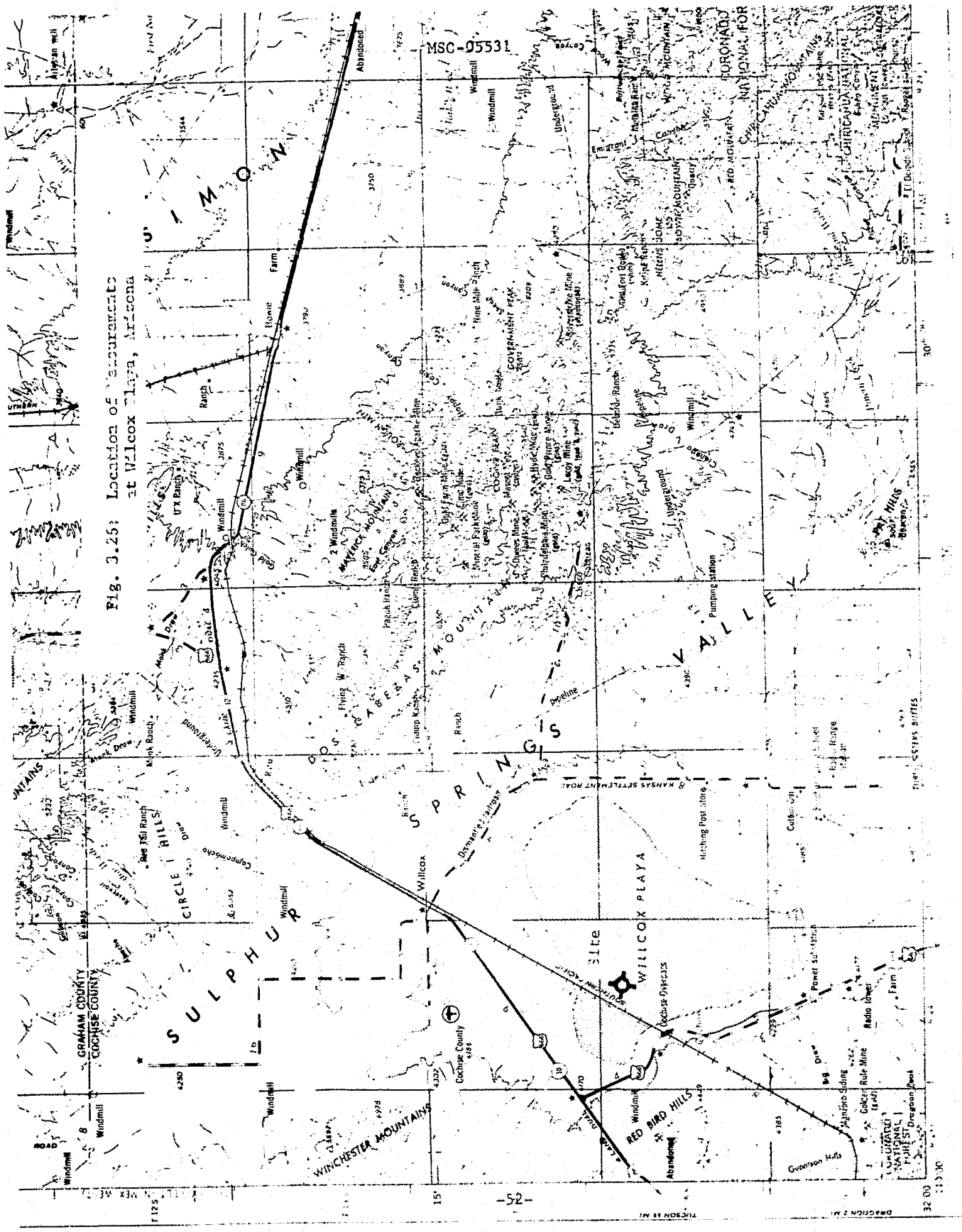
3.2.3.2 Near Surface Meteorology

Wet Bulb Temperature - 38°F

Dry Bulb Temperature - 49°F

3.2.3.3 Snow Brightness Temperature

-2.5°C at 1045 Local Time (MDT)



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3.2.3.4 General Conditions

High cirrus clouds were present and made atmospheric conditions variable.

# APPENDIX A

# INSTRUMENT CALIBRATIONS, OPERATIONS, AND TECHNIQUES

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# 1.0 CALIBRATION AND ANALYSES TECHNIQUES FOR THE ROCKETSONDE SYSTEM

## 1.1 TEMPERATURE

The temperature range is divided into 400 data points of 8 ranges and 50 data points per range. The level of the current is essentially linear in relationship to temperature. To calibrate the temperature a potentiometer is adjusted in the field just prior to launch. The potentiometer adjusts the slope of current versus temperature and is adjusted to correspond to a specific data point on the calibration readout table. The specific data point is the ambient temperature as measured with a mercury thermometer.

## 1.2 HUMIDITY

The humidity range is divided into 200 data points of 4 ranges and 50 data points per range. As with temperature the current is essentially linear in relationship to the humidity as related to the carbon resistance gradient across the hygristor. There also exist 4 different current ratios with respect to temperature, the center of the ranges at $-40^{\circ}C$, $0^{\circ}C$, $+25^{\circ}C$, and $+40^{\circ}C$. To calibrate the humidity sensor in the field a precision 20k ohm resistor replaces the hygristor and corresponds to 33% humidity on all temperature ranges. With the resistor in place the humidity calibration potentiometer is adjusted to correspond to 33% humidity from the humidity calibration table.

## 1.3 ANALYSIS TECHNIQUES OF ROCKETSONDE STRIPCHART DATA

### 1.3.1 General

The stripchart recorders, both temperature and humidity, travel at 2.5 sec/½" ± 1% and are lined in ½" divisions. During a normal launch, expulsion occurs where the afterbody is separated from the electronics package, 6-7 seconds after launch at approximately 3300 ft. The temperature electronics requires 4 time constants (10 sec.) to stabilize and the humidity electronics requires 2 time constants (5 sec.) to stabilize. At expulsion the afterbody descends on one parachute and the electronics on a separate parachute. The descent rate of the electronics is 24 to 26 ft/sec (7.315 to 7.925 meters/sec) under normal circumstances. The lower constant velocity is near sea level and the faster velocity is for higher altitudes A.S.L. Should the parachute not open or only partially deploy an assumption has to be made that rocket will free-fall with a certain amount of drag associated with the free fall. This was the case at both Lake Pleasant and Twin Lakes. The data sheets to which the stripcharts data is transposed is shown in Table A-I for an example. The first column defines the number of 1/4" divisions on the stripchart that have elapsed since expulsion. The second column is the range and specific data point at that instant on the stripchart. Example: 7-35.5 is range 7 and 35.5 magnitude out of a possible 50.0. The third column is the time expired since expulsion and is derived by multipling

ROCKETSONDE EVALUATION DATA

| NUMBER OF ¼" EXPULSION | RAW DATA FROM ST.CH. | TIME FROM EXPULSION | ALTITUDE REF: 5120 | ALTITUDE (ABSOLUTE)* | TEMP OR HUM FROM TABLE | COMMENTS |
|---|---|---|---|---|---|---|
| 3.30 | 7-43.5 | 8.25 sec | - 675 ft | 4445 ft | See table below | |
| 3.90 | 7-42.9 | 9.75 | - 942 | 4178 | for temperature | |
| 4.35 | 7-42.4 | 10.875 | -1152 | 3948 | | |
| 4.55 | 7-41.8 | 11.375 | -1282 | 3838 | | |
| 4.75 | 7-41.5 | 11.875 | -1397 | 3723 | | |
| 5.10 | 7-40.5 | 12.75 | -1611 | 3509 | | |
| 5.65 | 7-40.0 | 14.125 | -1977 | 3143 | | |
| 6.20 | 7-39.0 | 15.5 | -2380 | 2740 | | |
| 6.90 | 7-38.0 | 17.25 | -2948 | 2172 | | |
| 7.30 | 7-36.5 | 18.25 | -3300 | 1820 | | |

NOTES: After landing Temp. stabilized at 7-35.2 = 8-9.0=34.9°C

Field calibration was incorrect .·. correction factor must be applied and this was supplied by vendor of Rocketsonde.

$X = [400 + 50(R-1)] + D.P. \Rightarrow Y = (Cc/Xc)X \Rightarrow Data' = \frac{(Y-350)}{50} = I + Re$ .

where: R=scale; D.P.=Data Point; Cc=Correct Cal. (R=7,D.P.=48.7 => 748.7); Xc=X at incorrect Cal. D.P.; Data'=Corrected D.P.; I => Interger=corrected R; Re => Fractional remainder = % of 50 D.P.'s of full scale

*Above sea level

| D.P.=Raw Data | X | Y | I | D.P.' | TEMP. |
|---|---|---|---|---|---|
| 7-25.2 | 725.2 | 748.7 | 7 | 48.7 | 31.8°C |
| 7-43.5 | 743.5 | 767.59 | 8 | 17.6 | 37.6 |
| 7-42.9 | 742.9 | 766.97 | 8 | 17.0 | 37.4 |
| 7-42.4 | 742.4 | 766.45 | 8 | 16.5 | 37.2 |
| 7-41.8 | 741.8 | 765.84 | 8 | 15.8 | 37.0 |
| 7-41.5 | 741.5 | 765.53 | 8 | 15.5 | 36.9 |
| 7-40.5 | 740.5 | 764.50 | 8 | 14.5 | 36.6 |
| 7-40.0 | 740.0 | 763.98 | 8 | 14.0 | 36.4 |
| 7-39.0 | 739.0 | 762.95 | 8 | 13.0 | 36.1 |
| 7-38.0 | 738.0 | 761.91 | 8 | 11.9 | 35.8 |
| 7-36.5 | 736.5 | 760.37 | 8 | 10.4 | 35.3 |

TEMPERATURE X HUMIDITY ____ LOCATION Pleasant Lake, AZ

DATE 06-03-73

NOTES: 1. Recorder travels at 2.5 sec/¼" div.
2. Parachute did not open.
3. Time to landing from expulsion = 18.25 sec. Upon vendors recommendation, assume an expulsion altitude of 3300 ft and v = 0 ft/sec. Altitude and dv/dt => ½ at$^2$ = A, where: A = Altitude; a = acceleration descent constant; and t = time. ½ a $(18.25)^2$ = 3300 => a= 19.8161

TABLE A-I. Pleasant Lake Rocketsonde Temperature Data Sheet

column 1 by 2.5. The fourth column defines the altitude descended from expulsion and is derived from the descent velocity. The fifth column is the altitude A.S.L. This is derived by adding 3300 ft (1.005km) to the ground level, or if the sonde was dropped the altitude at drop becomes the reference. The fourth column is then subtracted to give the altitude A.S.L. The sixth column is a direct conversion of the raw data from the calibration tables.

1.3.2 Lake Pleasant, AZ Profile

Two problems occurred; incorrect field calibration of temperature and the parachute did not deploy. The first problem was corrected by consulting with the manufacturer of the rocketsonde who provided MMC with a conversion formula to convert an incorrect current slope to the correct one. The current slope and formula have been explained in the above paragraph and Table A-I. The second problem was corrected by applying a drag influenced free-fall formula $A = 1/2\ a\ t^2$, where: A is altitude, t is time, and a is an acceleration descent constant. At Lake Pleasant the expulsion altitude assumed was 3300 ft (1.005km). The sonde descended to the ground in 18.25 seconds. This was found by finding the number of 1/4" (7.30) between expulsion and landing and multiplying that number by 2.5. Next the constant "a" is calculated by inserting the time and altitude into the free fall formula $A = 1/2\ a\ t^2$; this gives an acceleration of 19.816 $ft/sec^2$. The altitude

was calculated at any point in time between expulsion and landing by using 1/2 (19.81) $t_1^2$ = 3300-A, Table A-I shows the conversion of raw data to temperature as a function of altitude and table A-II shows the conversion of raw data to humidity as a function of altitude.

1.3.3 Vallecito Reservoir, CO, Profile

The only deviation from a normal launch was the sonde electronics package was dropped from a helicopter at 15,000 ft (4.57km) A.S.L. For data reduction purposes, that altitude is considered the expulsion altitude. The rest of the data reduction follos the basic format as explained previously. Table A-III shows the conversion of raw data to temperature as a function of altitude and Table A-IV shows the conversion of raw data to humidity as a function of altitude.

1.3.4 Twin Lakes Reservoir, CO, Profile

A problem with parachute deployment was once more encountered. The afterbody remained attached and was entangled in the parachute and the electronics package. The free fall formula explained previously was applied. The time from expulsion to landing was 45.75 seconds, indicating an acceleration of 3.15 ft/sec$^2$. The altitude was calculated at any point in time between expulsion and landing by using 1/2 (3.153) $t_1^2$ = 3300 - A, Table A-V shows the conversion of raw data to temperature versus altitude and table A-VI shows the conversion of raw data to humidity versus altitude.

### 1.3.5 Temperature/Humidity Lag With Respect to Altitude

Due to the response times of the temperature and humidity sensors, their exists a lag between the temperature and humidity readings and the exact altitude that they were actually encountered. This lag time translates to an altitude lag, depending upon the descent velocity of the sensors.

In all cases (Lake Pleasant, Vallecito, and Twin Lakes) four time constants (10 sec) for the temperature sensor, and two time constants (5 sec) for the humidity sensor were allowed for initial stabilization with the atmosphere. After this initial stabilization, the manufacturer advises a maximum of 2.5 second response time* for the temperature sensor and a 1.5 second response time* for the humidity sensor, for the nominal descent rate of 25 ft/sec.

The Vallecito data was nominal, having a descent rate of 25 ft/sec. This results in a maximum of a 62 ft. altitude vs. temperature lag and a 38 ft. altitude vs. humidity lag. Considering the total altitude coverage was slightly greater than 7,000 ft. the altitude vs. temperature/humidity lag is not considered to be significant for the Vallecito profile.

The Twin Lakes and Pleasant Lake data were taken with the sensors accelerating toward the ground. Therefore, the altitude vs. temperature humidity lag is a function of altitude. The magnitude of this lag is determined by the acceleration of the sensor, the response time of the sensor, and the amount of elapsed time from sensor expulsion from the rocket (at 3300 ft. above terrain). The mean altitude lag ($\Delta z$) over a given time interval can be derived by

$$\Delta z = \left( \frac{t_n + t_{n-1}}{2} \right) \times a \times RT$$

*Based on private communications with the manufacturer, these time responses represent a worst case situation.

where $t_n$ is a given point in time in the descent, corresponding to the "time from expulsion" given in Tables A-1, A-II, A-III, A-IV, A-V, and A-VI; and $t_{n-1}$, is the time corresponding to the immediate preceding interval. The term a is the acceleration constant, and RT is the response time of the sensor. The corrected altitude (Z) that corresponds to the temperature/ humidity values given in the above tables is then

$$Z = Z' + \Delta z$$

where $Z'$ is the altitude given in the above table. The corrected altitudes have been computed in this manner and are listed in the following tables.

ROCKETSONDE EVALUATION DATA

| NUMBER OF ½ EXPULSION | RAW DATA FROM ST.CH. | TIME FROM EXPULSION | ALTITUDE REF: 5120 | ALTITUDE (ABSOLUTE)* | TEMP OR HUM FROM TABLE | COMMENTS |
|---|---|---|---|---|---|---|
| 2.60 | 1-23.2 | 6.5 sec | - 419 ft | 4701 ft | 35 % | |
| 3.20 | 1-23.0 | 8.0 | - 634 | 4486 | 34.5 | |
| 3.90 | 1-23.1 | 9.75 | - 942 | 4178 | 34.5 | |
| 4.40 | 1-23.8 | 11.0 | -1199 | 3921 | 35.5 | |
| 5.15 | 1-24.5 | 12.875 | -1642 | 3478 | 36 | |
| 5.90 | 1-25.0 | 14.75 | -2156 | 2964 | 37 | |
| 6.60 | 1-25.7 | 16.5 | -2697 | 2423 | 38 | |
| 7.30 | 1-25.7 | 18.25 | -3300 | 1820 | 38 | |

NOTE: Upon landing stripchart indicated a sharp decrease in humidity but it is believed Hygristor was dislodged from rocket upon impact.

*Above sea level

TEMPERATURE ____ HUMIDITY X LOCATION Pleasant Lake, AZ

DATE 06-03-73

NOTES: 1. See notes on Temperature Data Sheet

TABLE A-II. Pleasant Lake Rocketsonde Humidity Data Sheet

ROCKETSONDE EVALUATION DATA

| NUMBER OF EXPULSION | RAW DATA FROM ST.CH. | TIME FROM EXPULSION | ALTITUDE REF: 15,000 | ALTITUDE (ABSOLUTE)* | TEMP OR HUM FROM TABLE | COMMENTS |
|---|---|---|---|---|---|---|
| 1.00 | 4-28.7 | 2.50 sec | - 65ft | 14,935 ft | - 0.60°C | |
| 3.85 | 4-30.9 | 9.62 | - 250 | 14,750 | - 0.35 | |
| 7.70 | 4-34.5 | 19.29 | - 500 | 14,500 | + 0.30 | |
| 11.54 | 4-37.0 | 28.85 | - 750 | 14,250 | 0.75 | |
| 15.38 | 4-39.5 | 38.46 | -1,000 | 14,000 | 1.15 | |
| 19.23 | 4-43.0 | 48.08 | -1,250 | 13,750 | 1.70 | |
| 23.08 | 4-46.0 | 57.69 | -1,500 | 13,500 | 2.20 | |
| 26.92 | 5- 5.0 | 67.31 | -1,750 | 13,250 | 3.70 | changing sc. |
| 30.77 | 5- 6.2 | 76.92 | -2,000 | 13,000 | 3.90 | |
| 34.61 | 5-10.8 | 86.50 | -2,250 | 12,750 | 4.60 | |
| 38.46 | 5-15.0 | 96.15 | -2,500 | 12,500 | 5.30 | |
| 42.31 | 5-18.6 | 105.77 | -2,750 | 12,250 | 5.90 | |
| 46.15 | 5-23.0 | 115.38 | -3,000 | 12,000 | 6.65 | |
| 50.00 | 5-26.9 | 125.00 | -3,250 | 11,750 | 7.30 | |
| 53.85 | 5-31.2 | 134.62 | -3,500 | 11,500 | 8.00 | |
| 57.69 | 5-34.6 | 144.23 | -3,750 | 11,250 | 8.60 | |
| 61.54 | 5-38.9 | 153.85 | -4,000 | 11,000 | 9.30 | |
| 65.38 | 5-41.8 | 163.46 | -4,250 | 10,750 | 9.80 | |
| 69.23 | 5-47.0 | 173.08 | -4,500 | 10,500 | 10.70 | |
| 73.08 | | 182.69 | -4,750 | 10,250 | | Changing sc. |
| 76.92 | 6- 6.0 | 192.31 | -5,000 | 10,000 | 12.30 | |
| 80.77 | 6- 9.5 | 201.92 | -5,250 | 9,750 | 12.90 | |
| 84.62 | 6-12.9 | 211.54 | -5,500 | 9,500 | 13.55 | |
| 88.46 | 6-16.3 | 221.15 | -5,750 | 9,250 | 14.20 | |
| 92.30 | 6-21.2 | 230.77 | -6,000 | 9,000 | 15.10 | |
| 96.15 | 6-24.8 | 240.38 | -6,250 | 8,750 | 15.70 | |
| 100.00 | 6-27.6 | 250.00 | -6,500 | 8,500 | 16.25 | |
| 103.85 | 6-30.3 | 259.62 | -6,750 | 8,250 | 16.80 | |
| 107.69 | 6-30.8 | 269.23 | -7,000 | 8,000 | 16.90 | |
| 110.00 | 6-31.5 | 275.00 | -7,150 | 7,850 | 17.00 | |

*Above sea level

LAUNCH: 1210 MDT
LAND: 1215 MDT
TIME OF FLIGHT: 4 min 46 sec

TEMPERATURE X HUMIDITY ____ LOCATION Lake Vallecito, CO

DATE 06-05-73

NOTES: Rocketsonde was dropped from helicopter at 15,000 ft. ±100 ft, descent rate = 26 ft/sec

TABLE A-III. Vallecito Reservoir Rocketsonde Temperature Data Sheet

ROCKETSONDE EVALUATION DATA

| NUMBER OF ½" EXPULSION | RAW DATA FROM ST.CH. | TIME FROM EXPULSION | ALTITUDE REF: 15,000 | ALTITUDE (ABSOLUTE)* | TEMP OR HUM FROM TABLE | COMMENTS |
|---|---|---|---|---|---|---|
| 1.00 | 1-10.3 | 2.50sec | - 65ft | 14,935ft | 16.0 % | |
| 3.85 | 1-12.2 | 9.62 | - 250 | 14,750 | 18.0 | |
| 7.70 | 1-11.6 | 19.29 | - 500 | 14,500 | 17.0 | |
| 11.54 | 1-14.2 | 28.85 | - 750 | 14,250 | 20.0 | |
| 15.38 | 1-14.4 | 38.46 | -1,000 | 14,000 | 20.5 | |
| 19.23 | 1-13.5 | 48.08 | -1,250 | 13,750 | 19.0 | |
| 23.08 | 1-12.0 | 57.69 | -1,500 | 13,500 | 18.0 | |
| 26.92 | 1-13.0 | 67.31 | -1,750 | 13,250 | 19.0 | |
| 30.77 | 1-13.6 | 76.92 | -2,000 | 13,000 | 19.5 | |
| 34.61 | 1-13.0 | 86.60 | -2,250 | 12,750 | 19.0 | |
| 38.46 | 1-12.5 | 96.15 | -2,500 | 12,500 | 18.0 | |
| 42.31 | 1-12.0 | 105.77 | -2,750 | 12,250 | 17.7 | |
| 46.15 | 1-11.7 | 115.38 | -3,000 | 12,000 | 17.5 | |
| 50.00 | 1-12.6 | 125.00 | -3,250 | 11,750 | 18.3 | |
| 53.85 | 1-13.0 | 134.62 | -3,500 | 11,500 | 19.0 | |
| 57.69 | 1- 9.3 | 144.23 | -3,750 | 11,250 | 14.7 | |
| 61.54 | 1-10.0 | 153.85 | -4,000 | 11,000 | 15.5 | |
| 65.38 | 1-12.0 | 163.46 | -4,250 | 10,750 | 18.0 | |
| 69.23 | 1-11.5 | 173.08 | -4,500 | 10,500 | 17.0 | |
| 73.08 | 1- 9.5 | 182.69 | -4,750 | 10,250 | 15.0 | |
| 76.92 | 1- 9.0 | 192.31 | -5,000 | 10,000 | 14.5 | |
| 80.77 | 1- 7.0 | 201.92 | -5,250 | 9,750 | 12.5 | |
| 84.62 | 1- 6.5 | 211.54 | -5,500 | 9,500 | 12.0 | |
| 88.46 | 1- 4.2 | 221.15 | -5,750 | 9,250 | 9.7 | |
| 92.30 | 1- 4.9 | 230.77 | -6,000 | 9,000 | 10.5 | |
| 96.15 | 1- 4.0 | 240.38 | -6,250 | 8,750 | 9.5 | |
| 100.00 | 1- 4.5 | 250.00 | -6,500 | 8,500 | 10.0 | |
| 103.85 | 1-12.0 | 259.62 | -6,750 | 8,250 | 18.0 | reached 39% |
| 107.69 | 1-27.0 | 269.23 | -7,000 | 8,000 | 39.0 | at 8,070 ft |
| 110.00 | 1-27.0 | 275.00 | -7,150 | 7,850 | 39.0 | |

*Above sea level

LAUNCH: 1210 MDT
LAND: 1215 MDT
TIME OF FLIGHT: 4 min 46 sec

TEMPERATURE ____ HUMIDITY X LOCATION Lake Vallecito, CO

DATE 05-05-73

NOTES: See notes on temperature data sheet

TABLE A-IV. Vallecito Reservoir Rocketsonde Humidity Data Sheet

ROCKETSONDE EVALUATION DATA

| NUMBER OF ¼" EXPULSION | RAW DATA FROM ST.CH. | TIME FROM EXPULSION | ALTITUDE REF: | ALTITUDE (ABSOLUTE) * | TEMP OR HUM FROM TABLE | COMMENTS |
|---|---|---|---|---|---|---|
| 4.30 | 6- 8.5 | 10.75 sec | - 182 ft | 12,868 ft | 12.8 °C | |
| 5.025 | 6-12.0 | 12.56 | - 249 | 12,801 | 13.4 | |
| 6.1 | 6- 9.6 | 15.25 | - 367 | 12,683 | 12.95 | |
| 6.4 | 6-10.2 | 16.0 | - 404 | 12,646 | 13.1 | |
| 7.25 | 6-14.2 | 18.125 | - 518 | 12,532 | 13.8 | |
| 8.20 | 6-16.5 | 20.5 | - 663 | 12,387 | 14.2 | |
| 9.0 | 6-18.8 | 22.5 | - 798 | 12,252 | 14.6 | |
| 9.45 | 6-19.7 | 23.625 | - 880 | 12,170 | 14.8 | |
| 11.15 | 6-21.0 | 27.875 | -1225 | 11,825 | 15.0 | |
| 11.775 | 6-23.0 | 29.4375 | -1366 | 11,684 | 15.4 | |
| 12.35 | 6-24.3 | 30.875 | -1503 | 11,547 | 15.6 | |
| 12.9 | 6-24.8 | 32.25 | -1640 | 11,410 | 15.7 | |
| 13.45 | 6-25.0 | 33.625 | -1783 | 11,267 | 15.8 | |
| 13.85 | 6-25.3 | 34.625 | -1890 | 11,160 | 15.85 | |
| 14.4 | 6-26.7 | 36.0 | -2043 | 11,007 | 16.0 | |
| 15.4 | 6-27.5 | 38.5 | -2337 | 10,713 | 16.25 | |
| 16.25 | 6-29.7 | 40.625 | -2602 | 10,448 | 16.65 | |
| 16.75 | 6-31.0 | 41.875 | -2765 | 10,285 | 16.9 | |
| 17.0 | 6-32.4 | 43.0 | -2915 | 10,135 | 17.2 | |
| 17.6 | 6-33.6 | 44.0 | -3052 | 9,998 | 17.4 | |
| 17.9 | 6-31.5 | 44.75 | -3157 | 9,893 | 17.0 | |
| 18.05 | 6-32.3 | 45.125 | -3210 | 9,840 | 17.15 | |
| 18.3 | 6-31.5 | 45.75 | -3300 | 9,750 | 17.0 | |

*Above sea level

TEMPERATURE ___ HUMIDITY ___ LOCATION Twin Lakes Reservoir, CO

DATE 06-11-73

NOTES: 1. Recorder travels at 2.5 sec/¼" div.
2. Electronics and Afterbody attached to same parachute.
3. Time to landing from expulsion = 45.75 sec. Upon vendor's recommendation, assume an expulsion altitude of 3300 ft and v = 0 ft/sec. Altitude and $dv/dt \Rightarrow \frac{1}{2} at^2 = A$, where: A = Altitude; a = acceleration descent constant; and t = time. $\frac{1}{2} a (45.75)^2 = 3300 \Rightarrow a = 3.153274209$

TABLE A-V. Twin Lakes Rocketsonde Temperature Data Sheet

ROCKETSONDE EVALUATION DATA

| NUMBER OF ½' EXPULSION | RAW DATA FROM ST.CH. | TIME FROM EXPULSION | ALTITUDE REF: 13,050 | ALTITUDE (ABSOLUTE)* | TEMP OR HUM FROM TABLE | COMMENTS |
|---|---|---|---|---|---|---|
| 1.35 | 1-24.8 | 3.375 | - 18 ft | 13,032 ft | 36 % | |
| 2.0 | 1-25.2 | 5.0 | - 39 | 13,011 | 36.5 | |
| 3.0 | 1-26.0 | 7.5 | - 89 | 12,961 | 37.5 | |
| 4.0 | 1-26.3 | 10.0 | - 158 | 12,892 | 38 | |
| 5.0 | 1-27.0 | 12.5 | - 246 | 12,804 | 38.5 | |
| 6.0 | 1-27.0 | 15.0 | - 355 | 12,695 | 38.5 | |
| 7.0 | 1-27.5 | 17.5 | - 483 | 12,567 | 39 | |
| 8.0 | 1-28.0 | 20.0 | - 630 | 12,420 | 39.5 | |
| 9.0 | 1-28.0 | 22.5 | - 798 | 12,252 | 39.5 | |
| 10.0 | 1-28.5 | 25.0 | - 985 | 12,065 | 40 | |
| 11.0 | 1-29.1 | 27.5 | -1192 | 11,858 | 40.5 | |
| 12.0 | 1-29.5 | 30.0 | -1419 | 11,631 | 41 | |
| 13.0 | 1-38.5 | 32.5 | -1655 | 11,395 | 47.5 | |
| 14.4 | 1-41.0 | 36.0 | -2043 | 11,007 | 49 | |
| 14.75 | 1-45.5 | 36.875 | -2143 | 10,907 | 51 | |
| 15.65 | 1-46.1 | 39.125 | -2413 | 10,637 | 51.5 | |
| 16.7 | 1-46.5 | 41.75 | -2748 | 10,302 | 51.5 | |
| 18.0 | 2-14.5 | 45.0 | -3193 | 9,857 | 60.5 | Data from stripchart uncertain |
| 18.3 | 2-19.0 | 45.75 | -3300 | 9,750 | 62 | Data from stripchart uncertain |

*Above sea level

TEMPERATURE ____ HUMIDITY X LOCATION Twin Lakes Reservoir, CO

DATE 06-11-73

NOTES: 1. See notes on Temperature Data Sheet

TABLE A-VI. Twin Lakes Rocketsonde Humidity Data Sheet

## ROCKETSONDE ALTITUDE CORRECTIONS

| RAW (Z') FT | CORRECTION (ΔZ) FT | ACTUAL (Z) FT | TEMP. (°C) | $t_n + t_{(n-1)}$ | $a\left[\frac{t_n + t_{n-1}}{2}\right]$ |
|---|---|---|---|---|---|
| 4,445 | 204.4 | 4,649 | 37.6 | 8.25 | 85.741 |
| 4,178 | 445.9 | 4,624 | 37.4 | 18.0 | 178.345 |
| 3,948 | 510.9 | 4,458 | 37.2 | 20.625 | 204.354 |
| 3,838 | 551.1 | 4,389 | 37.0 | 22.25 | 220.454 |
| 3,723 | 575.9 | 4,299 | 36.9 | 23.25 | 230.362 |
| 3,509 | 609.96 | 4,119 | 36.6 | 24.625 | 243.986 |
| 3,143 | 665.7 | 3,809 | 36.4 | 26.875 | 266.279 |
| 2,740 | 733.8 | 3,474 | 36.1 | 29.625 | 293.526 |
| 2,172 | 811.2 | 2,983 | 35.8 | 32.75 | 324.489 |
| 1,820 | 879.3 | 2,699 | 35.3 | 35.5 | 351.736 |
| - | - | 1,820 | 34.9 | - | - |

**NOTES:** 2.5 SECONDS AFTER LANDING TEMPERATURE STABILIZED AT 34.9°C AND REMAINED AT THAT TEMPERATURE UNTIL GROUND STATION WAS TURNED OFF APPROXIMATELY 1 MINUTE LATER.

LOCATION PLEASANT LAKE, AZ

DATE 06-03-73

a = 19.8161 FT/SEC

RT = 2.5 SEC
(RESPONSE TIME)

**NOTES:**

1. $$\overline{\Delta Z} = \left[\left(\frac{t_n + t_{(n-1)}}{2}\right) a\right] RT$$

**TABLE A-X Pleasant Lake Reservoir Altitude Correction Sheet**

## ROCKETSONDE ALTITUDE CORRECTIONS

| RAW (Z') FT | CORRECTION (ΔZ) FT | ACTUAL (Z) FT | HUMIDITY (%) | $t_n + t_{(n-1)}$ | $a\left[\frac{t_n + t_{n-1}}{2}\right]$ | |
|---|---|---|---|---|---|---|
| 4,701 | 96.6 | 4,797 | 35 | 6.5 | 64.402 | |
| 4,486 | 215.5 | 4,702 | 34.5 | 14.5 | 143.667 | |
| 4,178 | 263.8 | 4,442 | 34.5 | 17.75 | 175.868 | |
| 3,921 | 308.4 | 4,229 | 35.5 | 20.75 | 205.582 | |
| 3,478 | 354.8 | 3,833 | 36 | 23.875 | 236.555 | |
| 2,964 | 410.6 | 3,375 | 37 | 27.625 | 273.710 | |
| 2,423 | 464.4 | 2,887 | 38 | 31.25 | 309.627 | |
| 1,820 | 516.5 | 2,336 | 38 | 34.75 | 344.305 | |

NOTE: UPON LANDING STRIPCHART INDICATED A SHARP RISE IN HUMIDITY; HYGRISTOR BELIEVED TO HAVE DISLODGED FROM ROCKET ON IMPACT.

LOCATION PLEASANT LAKE, AZ

DATE 06-03-73

a = 19.8161 FT/SEC

RT = 1.5 SEC (RESPONSE TIME)

NOTES:

1. $\overline{\Delta Z} = \left[\left(\frac{t_n + t_{(n-1)}}{2}\right) a\right] RT$

TABLE A-XI Pleasant Lake Reservoir Altitude Correction Sheet

ROCKETSONDE ALTITUDE CORRECTIONS

| RAW (Z') FT | CORRECTION (ΔZ) FT | ACTUAL (Z) FT | TEMP. (°C) | $t_n + t_{(n-1)}$ | $a\left[\frac{t_n + t_{n-1}}{2}\right]$ |
|---|---|---|---|---|---|
| 12,868 | 42.4 | 12,910 | 12.8 | 10.75 | 16.949 |
| 12,801 | 91.9 | 12,893 | 13.4 | 23.31 | 36.751 |
| 12,683 | 109.6 | 12,793 | 12.95 | 27.81 | 43.846 |
| 12,646 | 123.2 | 12,769 | 13.1 | 31.25 | 49.270 |
| 12,532 | 134.5 | 12,667 | 13.8 | 34.125 | 53.803 |
| 12,387 | 152.2 | 12,539 | 14.2 | 38.625 | 60.898 |
| 12,252 | 169.5 | 12,421 | 14.6 | 43.0 | 67.795 |
| 12,170 | 181.8 | 12,352 | 14.8 | 46.125 | 72.722 |
| 11,825 | 203.0 | 12,028 | 15.0 | 51.5 | 81.397 |
| 11,684 | 225.9 | 11,910 | 15.4 | 57.3125 | 90.361 |
| 11,547 | 237.7 | 11,785 | 15.6 | 60.3125 | 95.091 |
| 11,410 | 248.8 | 11,659 | 15.7 | 63.125 | 99.525 |
| 11,267 | 259.7 | 11,527 | 15.8 | 65.875 | 103.861 |
| 11,160 | 269.0 | 11,429 | 15.85 | 68.25 | 107.605 |
| 11,007 | 278.4 | 11,285 | 16.0 | 70.625 | 111.350 |
| 10,713 | 293.6 | 11,007 | 16.25 | 74.5 | 117.459 |
| 10,448 | 311.9 | 10,760 | 16.65 | 79.125 | 124.751 |
| 10,285 | 325.2 | 10,610 | 16.9 | 82.5 | 130.073 |
| 10,135 | 334.5 | 10,469 | 17.2 | 84.875 | 133.817 |
| 9,998 | 342.9 | 10,341 | 17.4 | 87.0 | 137.167 |
| 9,893 | 349.8 | 10,243 | 17.0 | 88.75 | 139.927 |
| 9,840 | 354.3 | 10,194 | 17.15 | 89.875 | 141.700 |
| 9,750 | 358.2 | 10,108 | 17.0 | 90.875 | 143.277 |

NOTE: TEMPERATURE SIGNAL LOST UPON IMPACT, NO FURTHER MEASUREMENTS OBSERVED.

LOCATION TWIN LAKES RESERVOIR, CO DATE 06-11-73

a = 3.1532

NOTES:

1. $\overline{\Delta Z} = \left[\left(\frac{t_n + t_{(n-1)}}{2}\right)a\right]RT$

TABLE A-XII Twin Lakes Reservoir Altitude Correction Sheet

## ROCKETSONDE ALTITUDE CORRECTIONS

| RAW (Z') FT | CORRECTION (ΔZ) FT | ACTUAL (Z) FT | HUMIDITY (%) | $t_n + t_{(n-1)}$ | $\sum \frac{t_n + t_{n-1}}{2}$ | |
|---|---|---|---|---|---|---|
| 13,032 | 8.0 | 13,040 | 36 | 3.375 | 5.321 | |
| 13,011 | 19.8 | 13,031 | 36.5 | 8.375 | 13.204 | |
| 12,961 | 29.6 | 12,991 | 37.5 | 12.5 | 19.708 | |
| 12,892 | 41.4 | 12,939 | 38 | 17.5 | 27.592 | |
| 12,804 | 53.2 | 12,857 | 38.5 | 22.5 | 35.476 | |
| 12,695 | 65.0 | 12,760 | 38.5 | 27.5 | 43.360 | |
| 12,567 | 76.9 | 12,644 | 39 | 32.5 | 51.244 | |
| 12,420 | 88.7 | 12,509 | 39.5 | 37.5 | 59.128 | |
| 12,252 | 100.5 | 12,353 | 39.5 | 42.5 | 67.012 | |
| 12,065 | 112.3 | 12,177 | 40 | 47.5 | 74.896 | |
| 11,858 | 124.2 | 11,982 | 40.5 | 52.5 | 82.773 | |
| 11,631 | 136.0 | 11,767 | 41 | 57.5 | 90.657 | |
| 11,395 | 147.8 | 11,543 | 47.5 | 62.5 | 98.540 | |
| 11,007 | 162.0 | 11,169 | 49 | 68.5 | 108.000 | |
| 10,907 | 172.3 | 11,079 | 51 | 72.875 | 114.897 | |
| 10,637 | 179.7 | 10,817 | 51.5 | 76.0 | 119.824 | |
| 10,302 | 191.3 | 10,493 | 51.5 | 80.875 | 127.511 | |
| 9,857 | 205.2 | 10,062 | 60 | 86.75 | 136.773 | |
| 9,750 | 214.6 | 9,965 | 62 | 90.75 | 143.080 | |

NOTE: HUMIDITY SIGNAL LOST UPON IMPACT, NO FURTHER MEASUREMENTS OBSERVED.

LOCATION TWIN LAKES RESERVOIR, CO DATE 06-11-73

a = 3.1532 FT/SEC RT = 1.5 SEC

NOTES:

1. $\overline{\Delta Z} = \left[\left(\frac{t_n + t_{(n-1)}}{2}\right) a\right] RT$

TABLE A-XIII Twin Lakes Reservoir Altitude Correction Sheet

## 2.0 CALIBRATION AND ANALYSES TECHNIQUES OF BRIGHTNESS TEMPERATURE

### 2.1 PRT-5 RADIATION THERMOMETER CALIBRATION TECHNIQUES

Calibration correction graphs, Figures A-1, A-2, A-3, have been derived by the Martin Marietta Metrology Laboratory. The graphs define the meter reading of brightness temperature that the Barnes PRT-5 reads as a function of the actual brightness temperature. This defines the calibration correction temperatures for the low (LO), medium (MED), and high (HI) ranges respectfully. Two curves are shown, one for a Colorado School of Mines (CSM), and one for a Martin Marietta Corporation (MMC) instrument.

Two methods were used to establish the correction factors. For temperatures below ambient temperature, a black body temperature equivalent was immersed in a dry ice and acetone controlled bath and allowed to stabilize for one-half hour at each temperature measured. The temperature was monitored by a stem thermometer calibrated by MMC Metrology Laboratory and is traceable to N.B.S. The method used to establish ambient and above ambient temperatures utilize a blackbody standard that was allowed to stabilize each temperature for approximately one hour. The standard was calibrated by MMC Metrology Laboratory and is traceable to N.B.S.

### 2.2 ANALYSIS TECHNIQUES OF PRT-5 BRIGHTNESS TEMPERATURE

#### 2.2.1 General

The measurements were written on field data sheets or directly on topographic maps. The only alteration of the raw

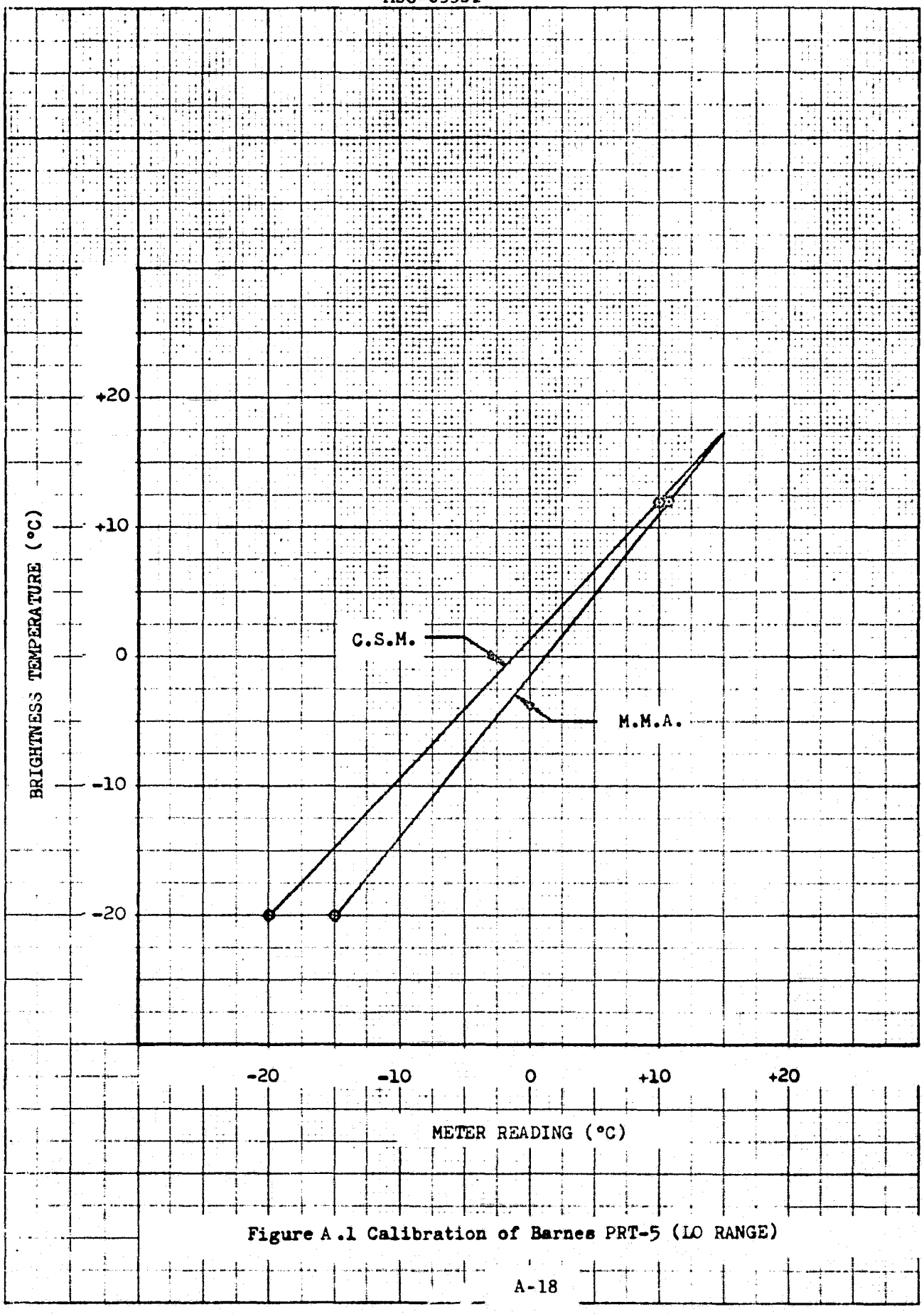


Figure A.1 Calibration of Barnes PRT-5 (LO RANGE)

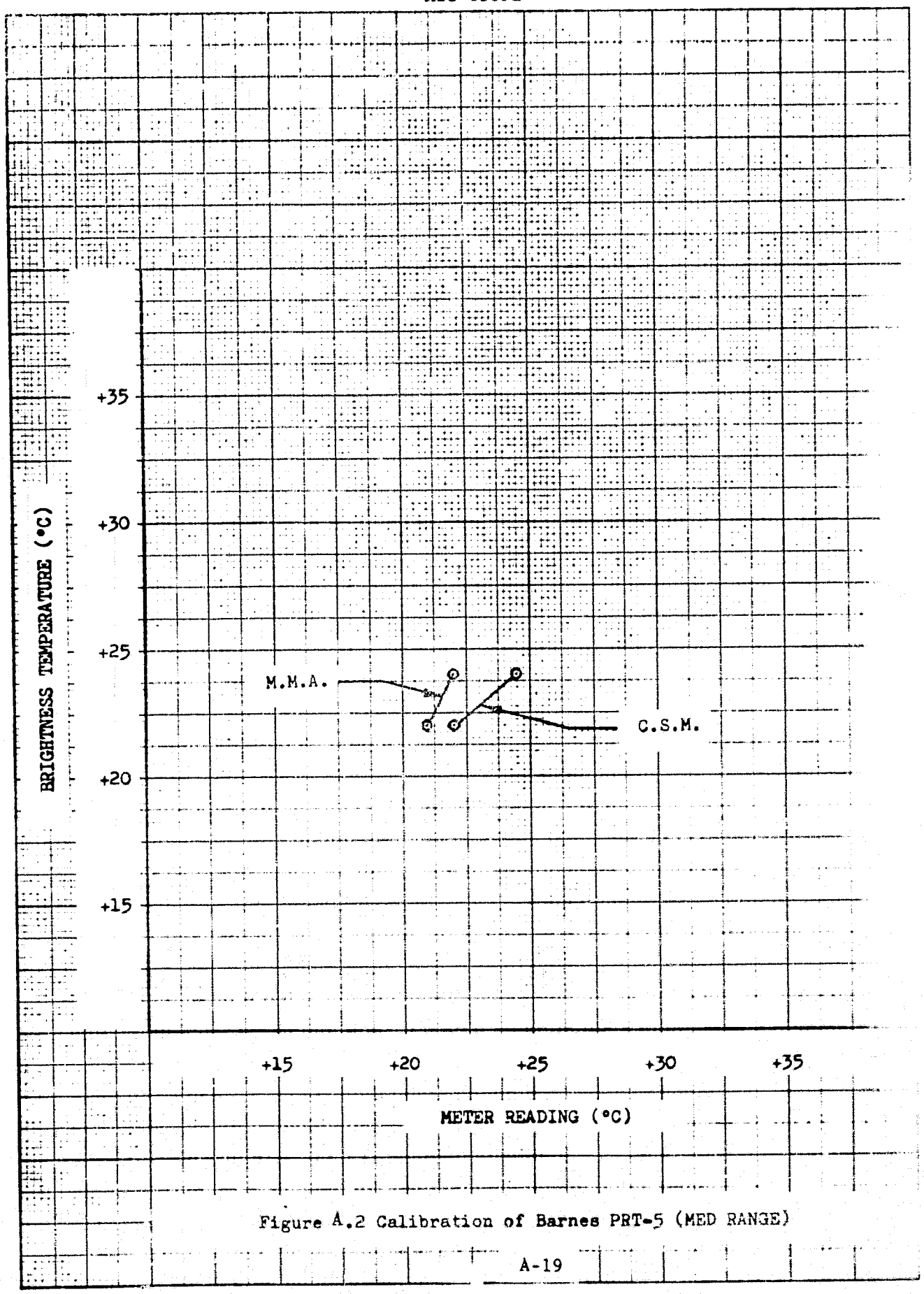


Figure A.2 Calibration of Barnes PRT-5 (MED RANGE)

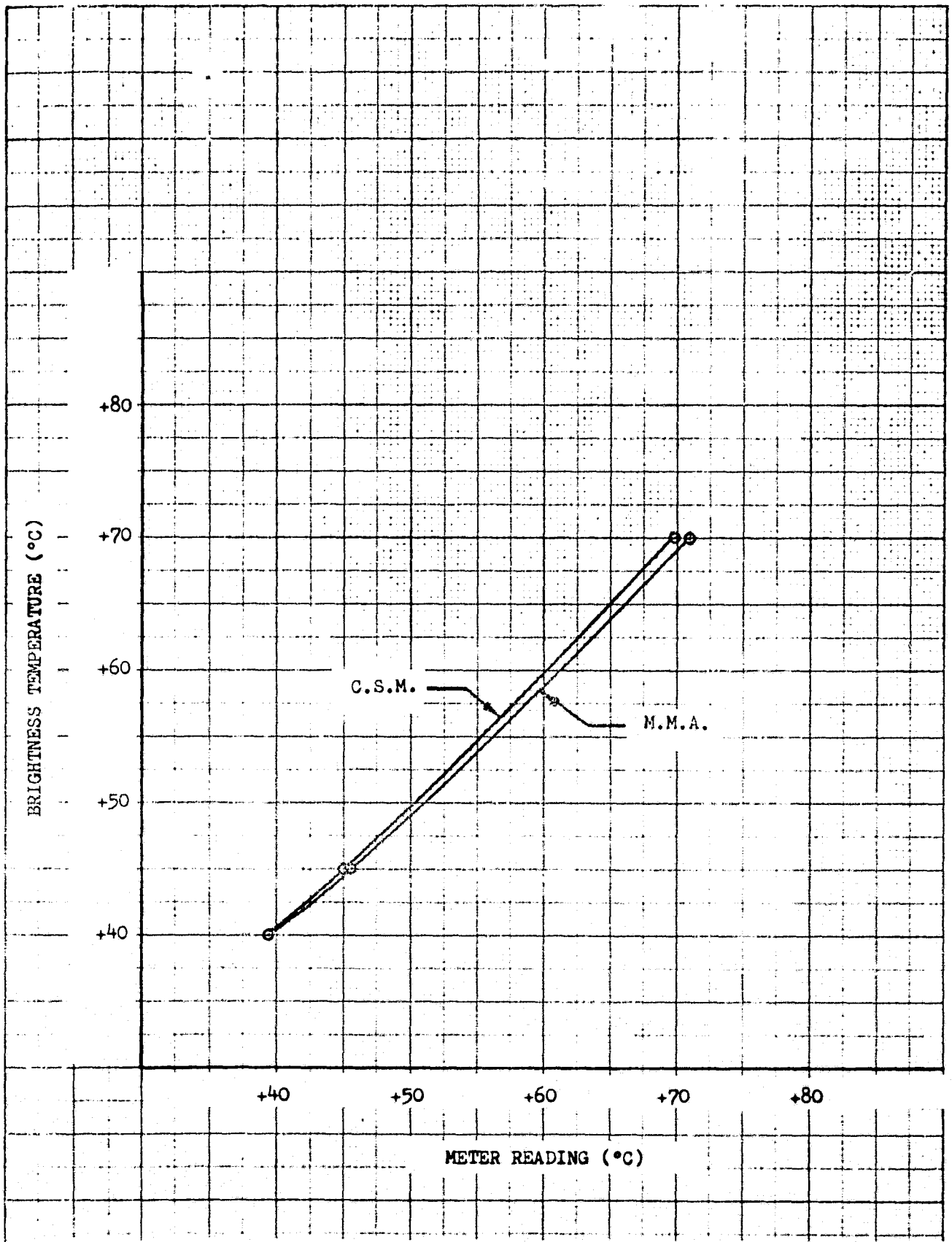


Figure A.3 Calibration of Barnes PRT-5 (HI RANGE)

data was the application of laboratory calibration correction factors. The field data sheet lists measurements taken at a particular site and includes local time of day, the surface temperature of the water as measured with a YSI mod 425C thermometer, the brightness temperature, the appropriate lake position, and any comments that describe surrounding conditions.

The map distributions have the corrected brightness temperature inserted. This conversion was accomplished by employing appropriate laboratory calibrations, Figures A.1, A.2 or A.3.

2.2.2 Lake Pleasant, AZ, Field Data

Table A-VII lists various surface meteorological measurements, surface water temperatures, and brightness temperatures.

2.2.3 Vallecito Reservoir, CO, Field Data

Table A-VIII lists only the surface water temperatures and brightness temperatures measured while in the boat -9 minutes to +16 minutes of overpass.

2.2.4 Twin Lakes Reservoir and Independence Pass CO Field Data

Table AVIX lists surface meteorological measurements and brightness temperature measurements taken while in the boat from -42 minutes to +12 minutes of overpass. Included is a brightness temperature measurement taken at the Independence Pass snow field located about 2,300 ft (701 meters) above Twin Lakes Reservoir and approximately 12 miles (20.92 km) to the west.



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WATER TEMPERATURE AND BRIGHTNESS TEMPERATURE

| RUN | TIME [MST] | SURFACE TEMP. [°C] | BRIGHTNESS TEMP. [°C] | LAKE POSITION | COMMENTS |
|---|---|---|---|---|---|
| | 1152 | 24.5/25.0 | 22.2 | 1 | Winds calm to slight, a few small clouds on horizon - some slight clouds above |
| | 1208 | 26.0/24.7 | 22.8 | 2 | Lake has slight waves, no white caps |
| | 1214 | 26.0/25.0 | 23.0 | 3 | |
| | 1219 | | | | 3 small clouds, (1%) coverage over lake. Site 3 in bright sun |
| | 1223 | 26.0/25.0 | 22.9 | 3 | |
| | 1226 | 26.0/25.0 | 22.9 | 3 | |
| | | | | | Cloud cover gone directly overhead, |
| | 1232 | | | | wet bulb 68°F dry bulb 81°F air temp. 28.5°C |
| | 1233 | 26.0/25.0 | 22.9 | 3 | |
| | 1246 | 26.0/25.0 | 22.6 | 4 | Slight clouds close to sun |
| | 1259 | 26.0/25.0 | 23.2 | 5 | No clouds overhead |
| | | | | Pos. 1 | Near boat ramp (200 yds) |
| | | | | Pos. 2 | Halfway up lake |
| | | | | Pos. 3 | Middle of large part of lake |
| | | | | Pos. 4 | 200 ft from point |
| | | | | Pos. 5 | West edge of lake |

NOTE: Lake was full
Slight haze(?) on horizon to south - clouds mostly on horizon to north
Rental boat - 12 ft / 9 hp

SITE Pleasant Lake, AZ MISSION EREP DATE Sun., Jun 3, 1973

EXPERIMENTER Kleen / Worman

INSTRUMENT Barnes PRT 5 (CSM) SER# 253 (BZ 70-5)

YSI Mod. 425C Thermometer 5167

°C Thermometer/°F Psychrometer

TABLE A-VII. Pleasant Lake Field Data Sheet

WATER TEMPERATURE AND BRIGHTNESS TEMPERATURE

| RUN | TIME [MDT] | SURFACE TEMP. [°C] | BRIGHTNESS TEMP. [°C] | LAKE POSITION | COMMENTS |
|---|---|---|---|---|---|
| 1 | 1150 | 12.50°C | 11.1 °C | Center | Air Temp. = 16.6°C |
| 2 | 1155 | 12.4 | 11.0 | Center | Air Temp. = 16.6 |
| 3 | 1200 | 12.7 | 11.3 | Center | Air Temp. = 16.6 |
| 4 | 1205 | 12.3 | 11.2 | Center | Air Temp. = 16.6 |
| 5 | 1210 | 12.2 | 11.0 | Center | Air Temp. = 16.6 |
| 6 | 1215 | 11.3 | 11.0 | Center | Air Temp. = 16.6 |

SITE Lake Vallecito, CO MISSION EREP DATE 06-05-73

EXPERIMENTER Worman

INSTRUMENT Barnes PRT-5 (C.S.M.) SER# 253 (BZ 70-5)

°C Thermometer

TABLE A-VIII. Vallecito Reservoir Field Data Sheet

## WATER TEMPERATURE AND BRIGHTNESS TEMPERATURE

| RUN | TIME [MDT] | SURFACE TEMP. [°C] | BRIGHTNESS TEMP. [°C] | LAKE POSITION | COMMENTS |
|---|---|---|---|---|---|
| | 0835 | | 10.8 | Middle | No wind, lake very smooth |
| | 0850 | | 10.0 | 1 | |
| | 0858 | | 10.0 | 2 | |
| | 0908 | | 10.0 | 3 | |
| | 0917 | | | | Wet bulb 49°F |
| | | | | | Dry bulb 62°F |
| | | | | | Air temp. 17°C |
| | 0920 | | 9.8 | 4 | |
| | 0929 | | 9.5 | 400 yds off Twin Lakes Lodge | |
| | 1045 | | -2.5 | Independance Pass Snow-field | Wet bulb 38°F |
| | | | | | Dry bulb 49°F |

SITE Twin Lakes Reservoir, CO MISSION EREP DATE 06-11-73

EXPERIMENTER Worman/ Jones/ Muhm

INSTRUMENT Barnes PRT 5 (CSM) SER# 253 (BZ 70-5)

°C Thermometer

°F Psychrometer

TABLE A-VIX. Twin Lakes Reservoir Field Data Sheet

## 3.0 I.S.C.O. SPECTRORADIOMETER CALIBRATION

The spectroradiometer was calibrated by viewing a standard lamp, traceable to N.B.S., and subsequently deriving a calibration factor. The calibration factor, CF, is given by:

$$CF = \frac{SLI}{SRI}$$

where SLI is the standard lamp intensity and SRI is the spectroradiometer raw intensity (output). Field data, SRI, is then multiplied by CF to give absolute intensity values of intensity. The values of CF for ISCO SR. #30109 are shown in Figure A.4.

Wavelength calibration is verified by periodically, both in the laboratory and field, inserting a Schott BG36 Filter in the light path. BG36 known absorption bands, as given by Schott and as measured on a Beckman DK-2, are used to check the wavelength response.

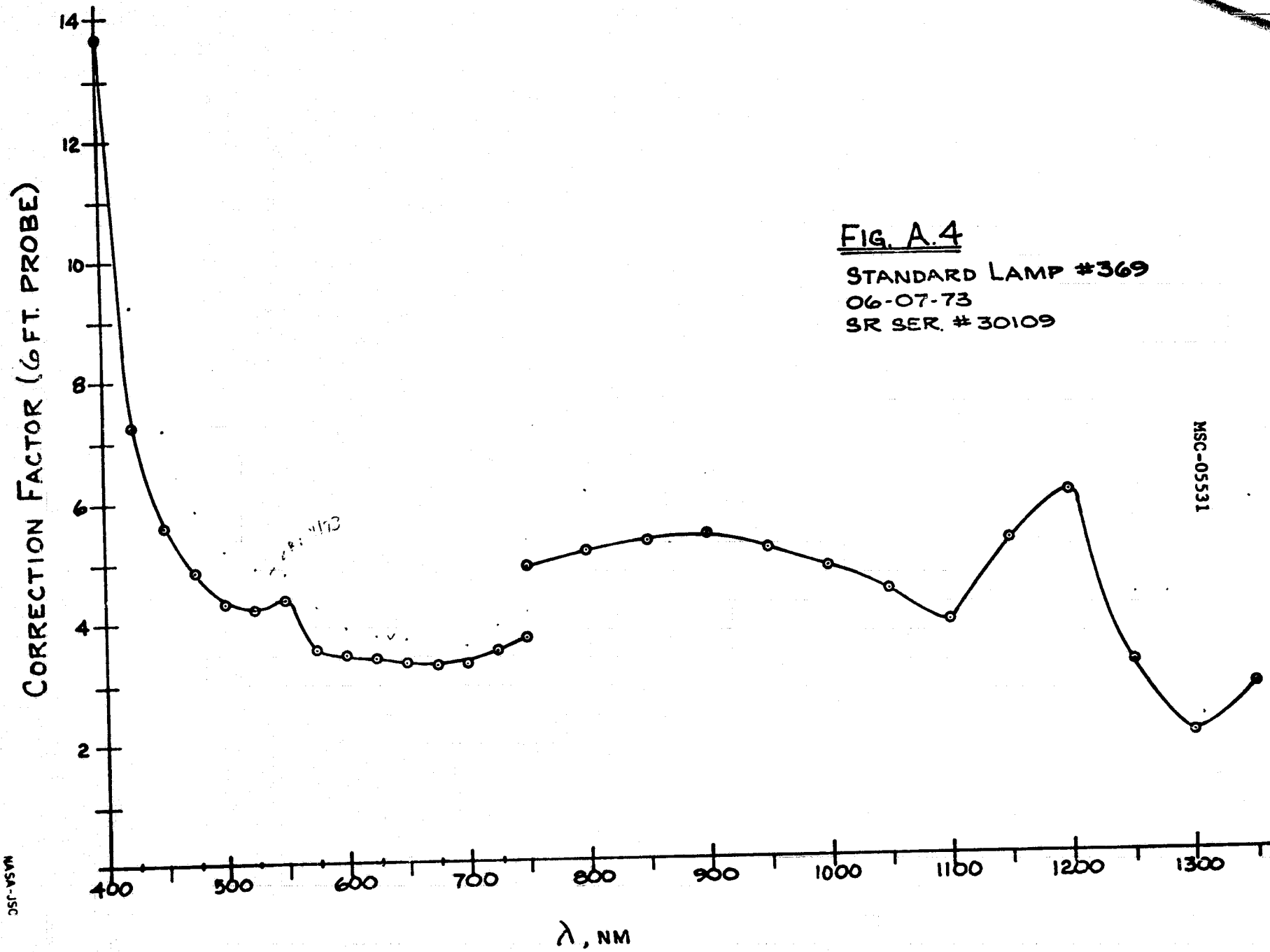


FIG. A.4

STANDARD LAMP #369
06-07-73
SR SER. #30109

MSC-05531



NASA-JSC